NASA Tech Briefs

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January 1995 Vol.19 No.1

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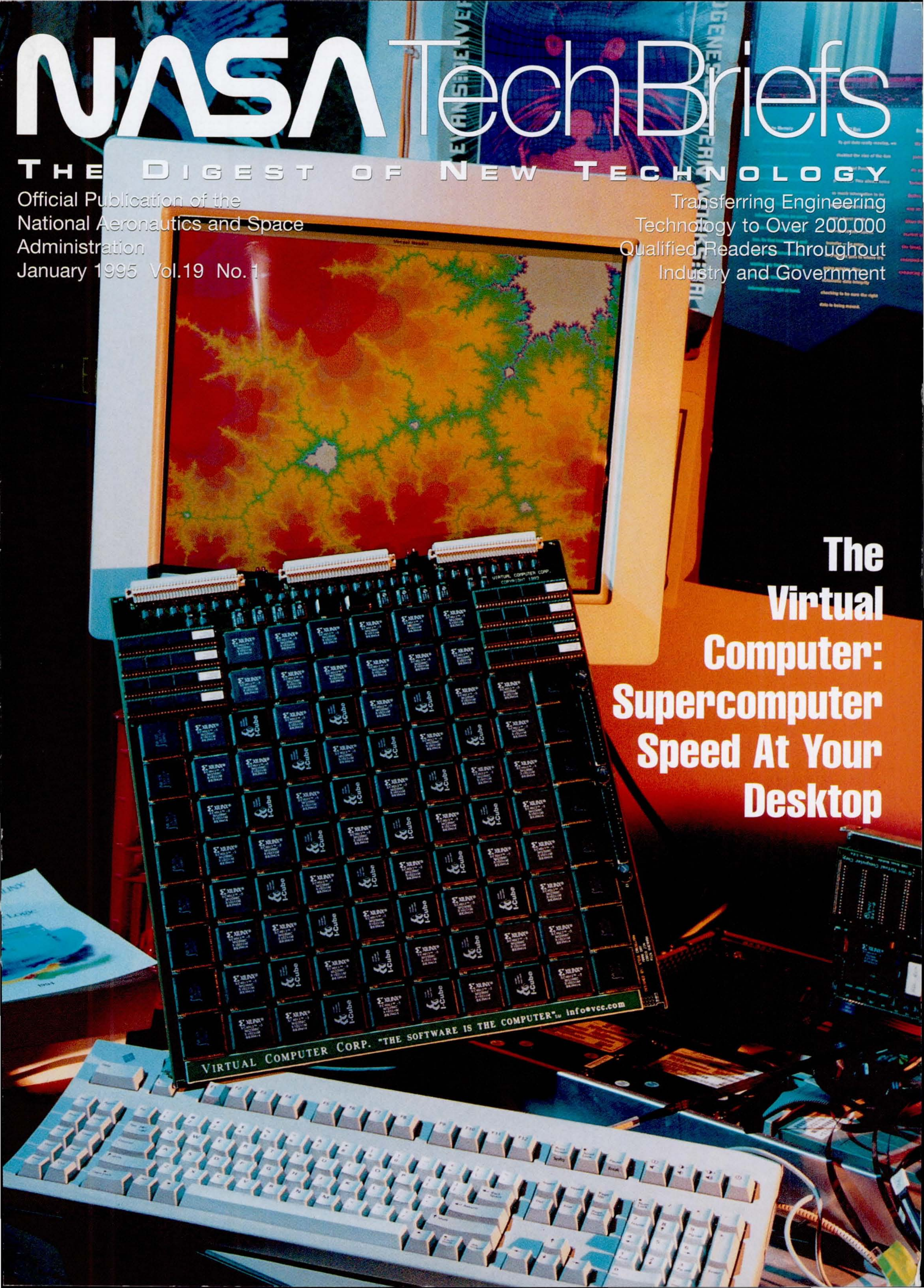

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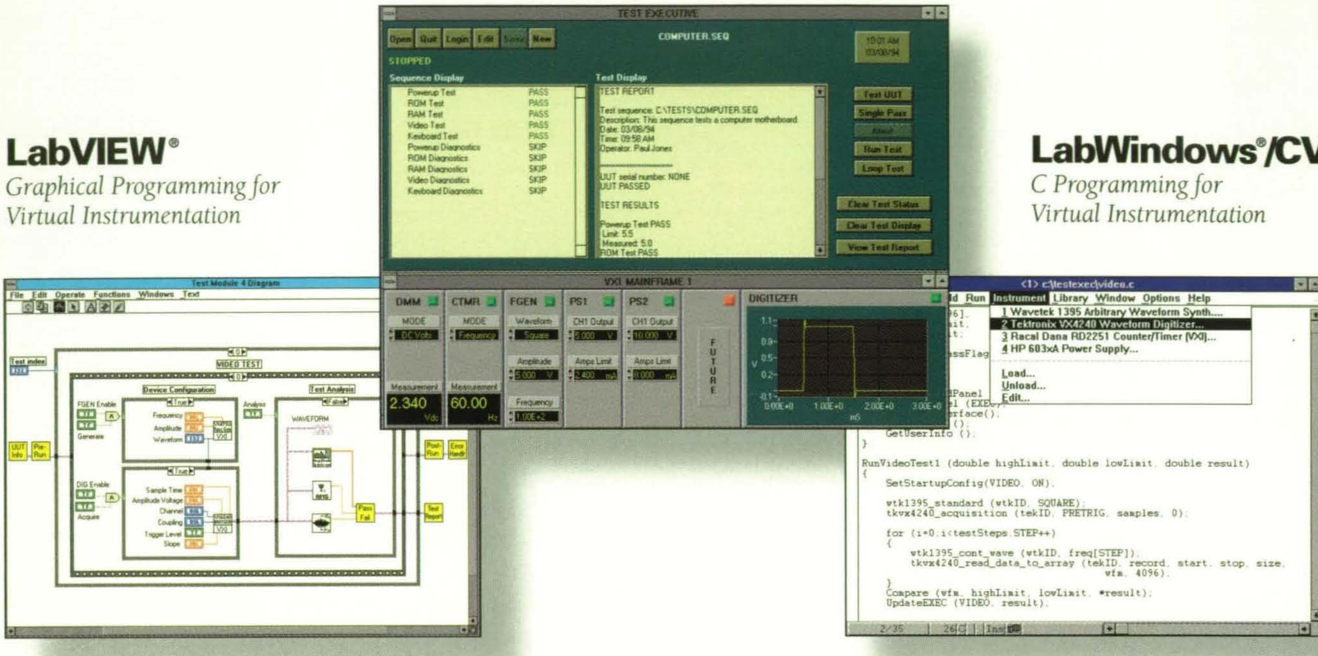

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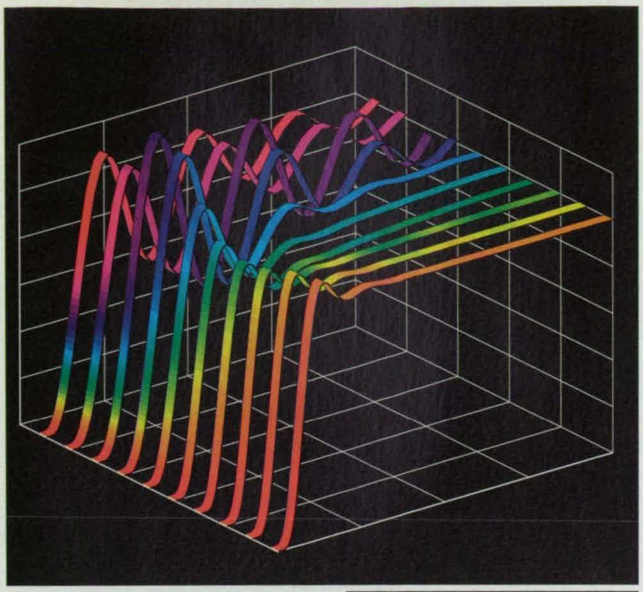

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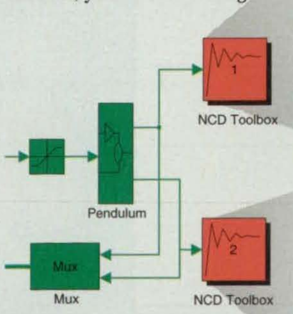

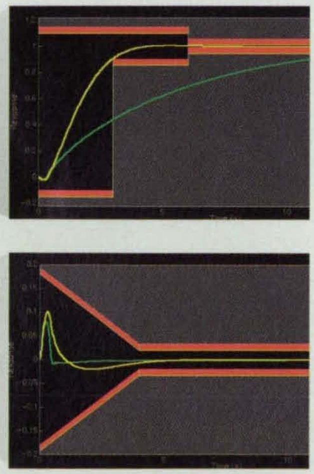

By connecting NCD Toolbox blocks to your nonlinear SIMULINK block diagram, you can shape multiple output signals simultaneously.

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(continued on page 8)

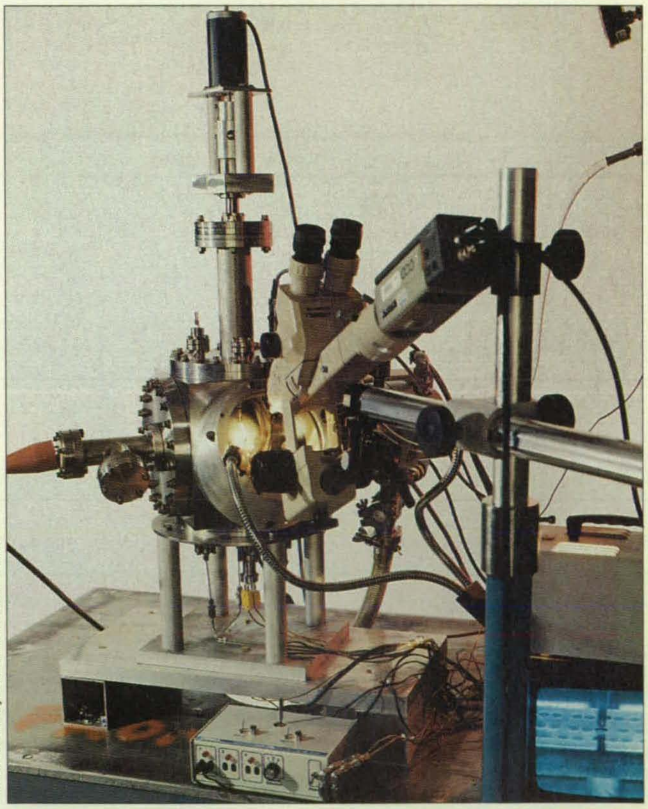
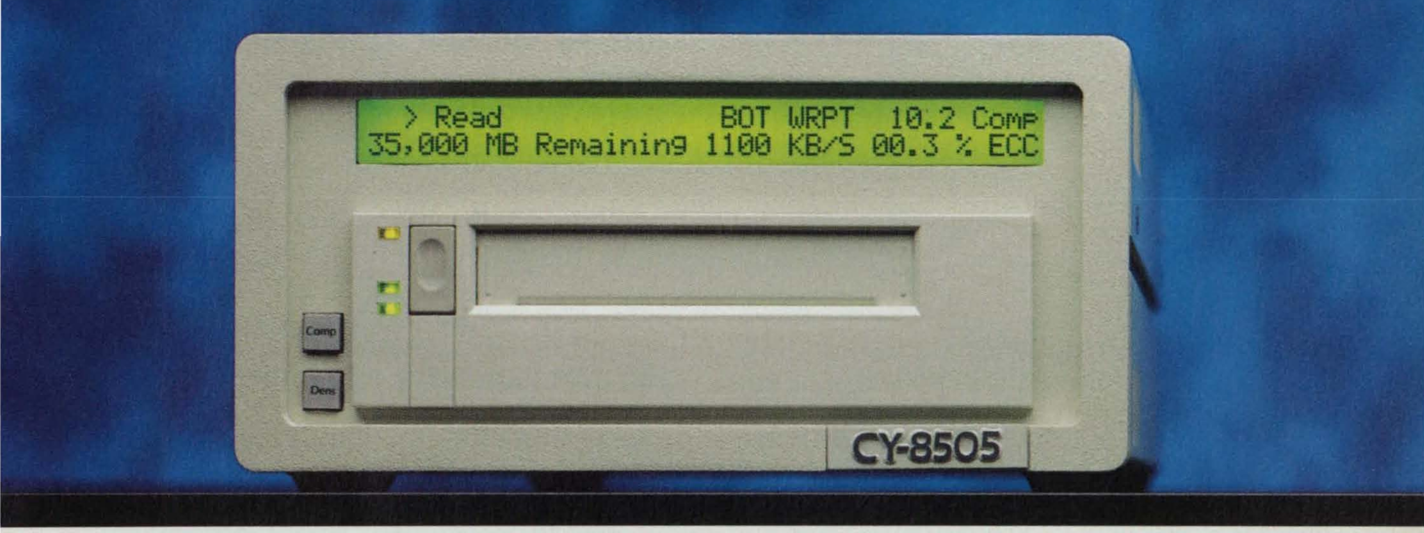


Photo courtesy Lewis Research Center

Lewis Research Center researchers have designed an apparatus that performs fiber-pushout testing—a technique for evaluating fiber/matrix interface strength in fiber-reinforced composites—at temperatures up to 1100 °C in a vacuum. Heating radiation from a quartz halogen lamp outside the test chamber is focused onto the specimen and indenter inside the chamber. See the tech brief on page 50.

The Only 35 GB Tape Drive With Fast SCSI Compression



All tape subsystems are not created equal. Only the CY-8505 can give you capacity of up to 35 GB and transfer rates as fast as 90 MB per minute.

That's because the CY-8505 is the only tape subsystem that features switch-selectable, Fast SCSI Compression. So you get the highest performance possible — and the lowest cost per megabyte.

A MTBF of 160,000 hours ensures reliability. The bit error rate of less than 1 in 10^{17} is the best in the industry. A backlit display gives you complete status information, including command under execution, transfer rate, compression ratio, tape remaining, and more.

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Convergent	IBM S/38	PC Xenix/Unix	Windows NT
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DEC BI-Bus	Macintosh	Plexus	
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Fast SCSI Compression can increase the native 7 GB capacity by as much as five times; *Accelerated File Access* (for Unix systems) allows you to locate a file in an average of 85 seconds; *Data Encryption* lets you control access to sensitive data through the use of uniquely encoded card keys; and the *Advanced SCSI Processor* allows multiple drives to work together in striping, mirroring, cascade and independent modes. You can even copy and verify tapes off-line.

Compatible with virtually every computer system and network, the CY-8505 is available in a single or dual desktop unit, in a rack mount configuration, or as part of a tape library system that can store as much as 3 TB.

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Contents (continued)

DEPARTMENTS

62 Materials

76 Computer Programs

78 Mechanics

86 Machinery

91 Fabrication Technology

95 Mathematics and Information Sciences

97 Life Science

99 Books and Reports

On the cover:
The Virtual Computer, a winner of one of the first SBIR Technology of the Year awards, promises to make supercomputer performance affordable on desktop workstations. Developed by Virtual Computer Corp., the unit employs massively reconfigurable, or programmable, logic to blur the line between hardware and software. Its field-programmable gate arrays permit reconfiguration to target specific applications in 250 milliseconds. ***Turn to page 17.*** *Photo courtesy Virtual Computer Corp.*

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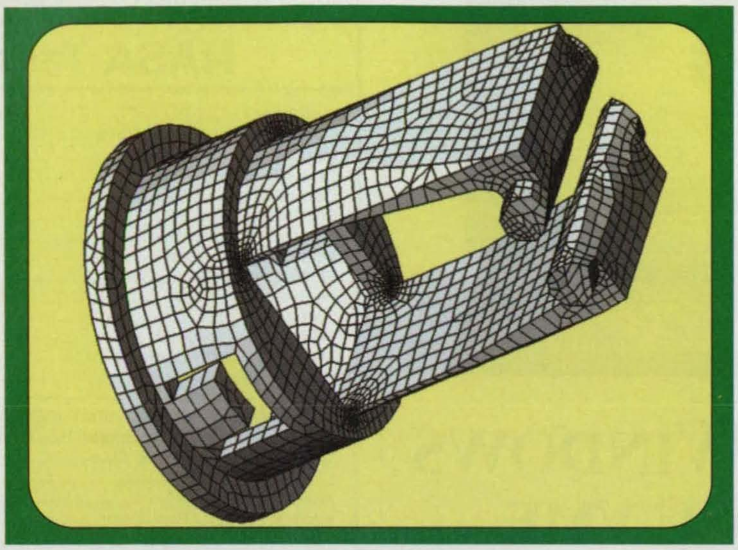
So, You Have MSC/NASTRAN* or PATRAN*. They're fine products...



8-Node "Brick" Model by Houdini. Operator time: 15 minutes.

...Now, Add Houdini™ and cut the cost of making 8-node "brick" finite element models up to 98%.

Here's how Houdini saves money when used with MSC/NASTRAN or PATRAN:

- Saves money by increasing modeling productivity an average of 92% compared to conventional region or volume-based techniques;
- Imports tetrahedral finite element models directly from PATRAN or Aries;
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Houdini saves money the first time you use it and for years to come.

Hourly cost for modeling (typical internal rate)	$75.00
Time required to build the solid model by hand:	16 hours
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Cost of Houdini example model:	$18.75
Money saved on example model using Houdini:	**$1,181.25**
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NASA Langley to Promote Partnerships With Industry at TOPS '95

NASA Langley's Technology Opportunities Showcase (TOPS) '95 will encourage successful partnerships with industry, such as a recent agreement between Ford Motor Company and Langley for the transfer of NASA-developed technology to improve the design and engineering of Ford vehicles.

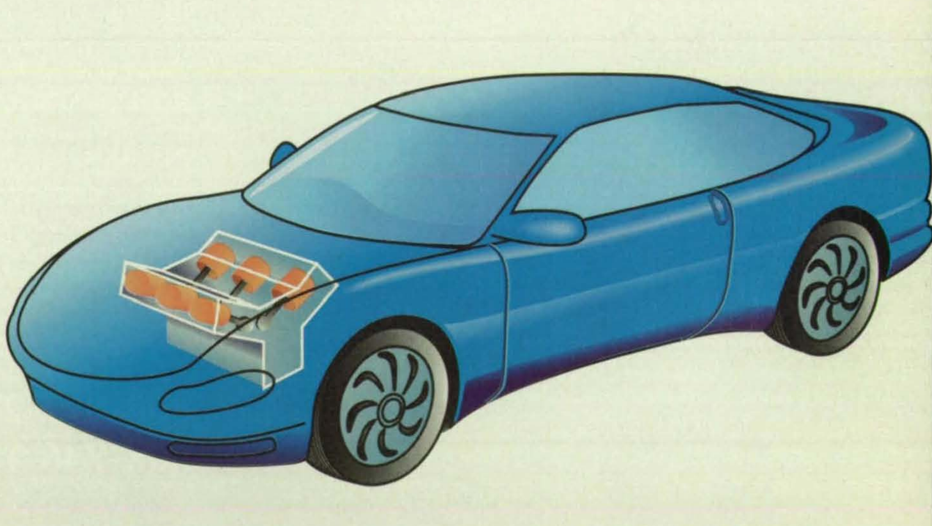
Langley Research Center's TOPS '95, which will be held April 6–8, 1995, at Langley in Hampton, Virginia, will help industry see first-hand the innovative technologies that can be transferred from NASA. These technologies include not only space and aeronautical research but also spinoffs in medicine, environmental science, materials development, and computer science, just to name a few. TOPS '95 will feature numerous exhibits of Langley-developed technology that is available for licensing and commercial development.

According to Jim Raper, TOPS Implementation Manager, TOPS '95 will be an even bigger event than TOPS '93. TOPS '93, which featured approximately 186 technical exhibits and was viewed by 850 representatives from 400 organizations, resulted in more than 3,500 requests for follow-up information. "Attendees also suggested previously unimagined potential applications for Langley technologies," said Raper. In TOPS '95, exhibits will be staffed by personnel directly involved in the development of the research, and attendees can again request post-TOPS follow-up information and contacts to enhance partnerships.

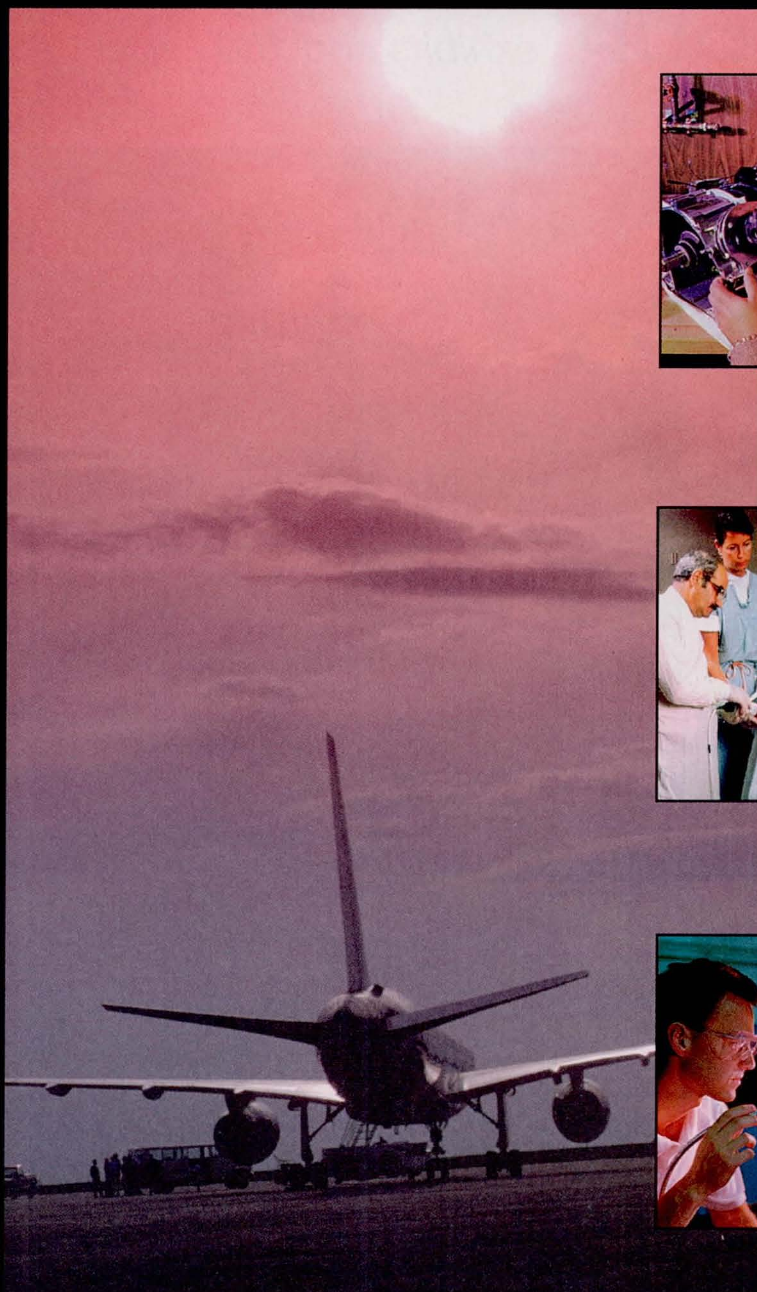
In fact, Langley has had many success stories from TOPS and other endeavors that link NASA research with partnerships in industry. Recently, Ford Motor Company of Dearborn, Michigan, agreed to a 2-year cooperative effort with NASA Langley. "By sharing technology with corporations like Ford, NASA is helping to increase the economic competitiveness of the nation," said Joseph Heyman, of the Langley Technology Applications Group. As David Hagen of Ford puts it, "This cooperative program will provide Ford with a tremendous amount of research to improve the design and engineering of our vehicles."

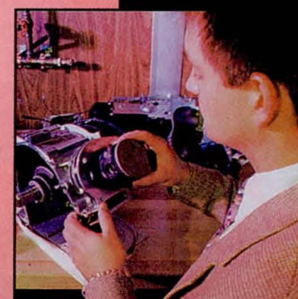
One of the Langley technologies that a number of corporations have reviewed is the carbon-carbon piston, which can withstand more heat than conventional engine materials. According to Langley engineers, these new pistons operate at higher temperatures, are two-thirds lighter, are more reliable at high power-output levels, may improve gas mileage, and can possibly produce less air pollution than current aluminum pistons. Rick Ruth, a Ford engineer, says that carbon-carbon pistons have great potential, even though they still need extensive research and development. According to Ruth, "They've [Langley] made a quantum leap improvement." Other potential commercial uses of carbon-carbon technology include oilless piston applications, recreational vehicle engines, and ultralight aircraft engines.

"TOPS '95 will be a chance for industry to identify new business opportunities. It will also be an exciting exposition for Langley and industry to form new partnerships," says Raper. For more information, contact Raper for a TOPS registration package.



Artist's concept of year-2000 car that uses carbon-carbon pistons developed with NASA Langley technology





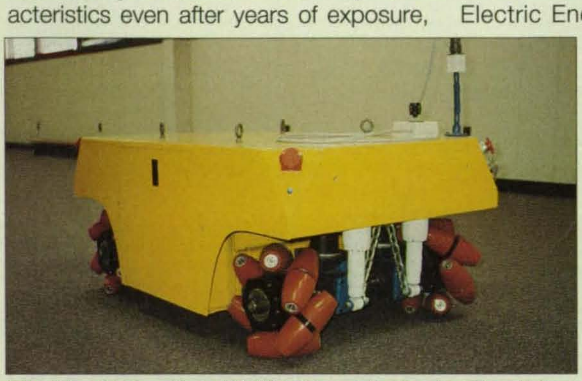
TECHNOLOGY 2004 ROUNDUP

Technology 2004, the fifth national technology transfer conference and exposition, was held at the Washington, DC, Convention Center November 8-10. Following are some highlights of the 250 exhibits and 100 papers presented.

Photo Robert L. Knudsen

Naval Surface Warfare's Coastal Systems Station in Panama City, FL (Tel. 904-235-5046), presented its Omni-Directional Vehicle (ODV). The design relies on the omni wheel patented by a Swedish inventor in 1973, in which each of the non-steerable wheels has its own drive motor. Rotating the wheel causes it to move on the ground at a 45° angle to its plane of rotation. By summing the motions created by each of the wheels, the vehicle can move in any direction. Developed for shipboard environments requiring low traction or steep and shifting inclines, the ODV also exhibits versatility in warehousing tasks, such as handling missile containers. Potential civilian applications include wheelchairs, hazardous waste cleaning, and motion picture camera platforms.

The WC series of conventionally applied, ambient-cured fluorinated polyurethane (FPU) coatings was exhibited by 21st Century Coatings, Alexandria, VA (Tel. 703-914-9277). Created by the Naval Research Laboratory and manufactured by 21st Century, the coatings have the superior properties of fluoropolymers but also are easy to apply and clean. According to the company, the coatings show no weathering characteristics even after years of exposure, are completely insensitive to UV radiation, and are electromagnetically and optically neutral. Further, they are impervious to water and oil and lack nutrients on which organisms can feed. Their low surface tension simplifies cleaning. Grover Howard of 21st Century said that the hull of a tug treated with the coating "was wiped clean with rags after a year in the water." 21st Century's Eugene Lindsey suggested an aeronautical application: if it were applied to aircraft exteriors, "ice would have a hard time sticking to them in the air."



The Omni-Directional Vehicle's omni wheels allow it to change direction instantly. Photo courtesy of Naval Coastal Systems Center

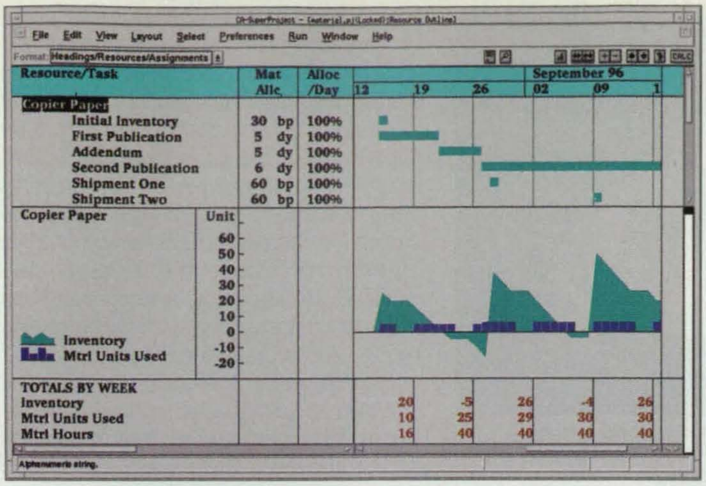
Operating under a Cooperative Research and Development Agreement (CRADA), the Naval Undersea Warfare Center and the Connecticut Municipal Electric Energy Cooperative (Norwich, CT, Tel. 203-889-4088) engineered an Electric Vehicle Monitoring and Display System to evaluate the vehicle's performance and display the information to the driver. The system's critical components include a sensor subsystem that measures data—particularly electrical—pertinent to performance evaluation. It uses a notebook computer and data acquisition system to collate the information, allowing analysts to evaluate electrical vehicle technologies consistently. The instrument cluster replaces the standard internal combustion engine cluster; not only should the new cluster promote safe vehicle operation, it should help the driver increase operating efficiency.

Agricultural Products

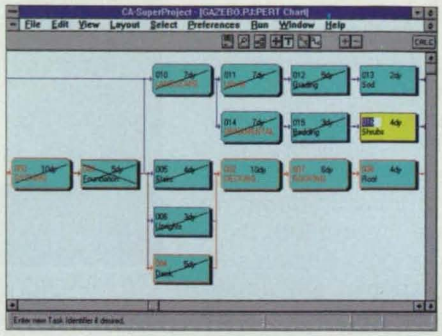
Researchers at the USDA's National Center for Agricultural Utilization Research, Peoria, IL (Tel. 309-685-4011), described the use of soybean oil in a newspaper and printing vehicle designed to replace petroleum-based inks. Because soybean oil has a greater penetration into newsprint than petroleum, inks based on soy are less prone to rub off on a reader's hands, as commonly occurs with newspapers. The researchers developed soybean vehicles (the hydrophobic bases into which pigments are mixed to

Inks made using a soybean oil base do not rub off on readers' hands as easily as conventional inks. Photo Keith Weller

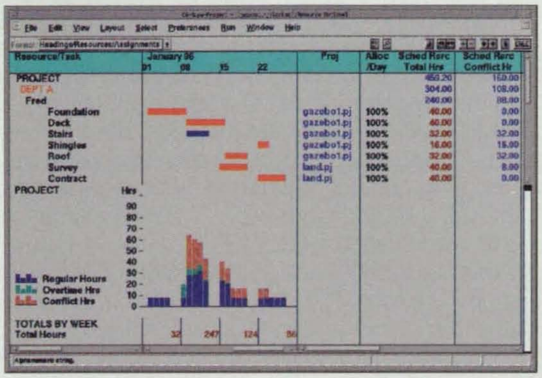
continued on page 16

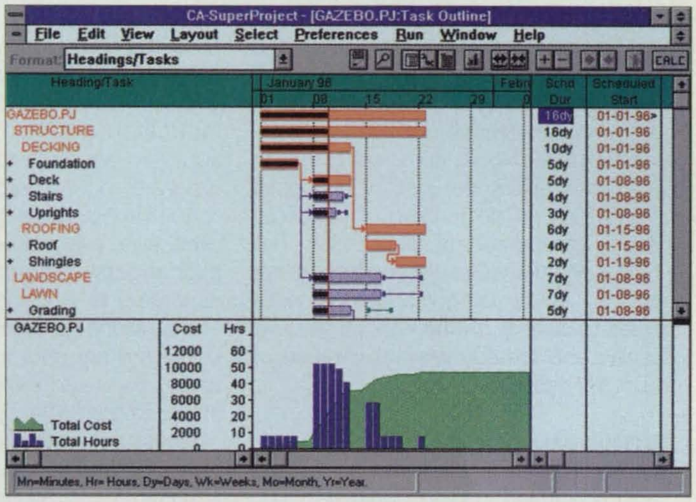


Track and manage the production, inventory and use of materials in addition to the management of labor, equipment and other resources.



Change project views to see WBS or PERT charts showing dependency links, milestones and status.





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continued from page 14
make inks) that can take either black or color pigments. They also are investigating the possibility that soybean inks are biodegradable, making them more attractive for landfill runoff concerns.

Another USDA researcher, working at the department's Agricultural Research Service, Columbia, MO (Tel. 314-875-5361), devised a technology that could stem the $300 million annual loss due to certain cotton pests. Known as the cotton bollworm and tobacco budworm, these pests are controlled using pyrethroid insecticides. Because the eggs of the two species are virtually indistinguishable, growers typically use pyrethroids whenever either or both have infested their crops. Upon repeated exposure to the chemicals, however, the budworm becomes resistant, while the bollworm does not. This often results in costly and ineffective spraying of budworm populations, exacerbation of pyrethroid resistance, loss of biological control through destruction of beneficial insects, and environmental pollution. The USDA's Matthew Greenstone has developed an assay using monoclonal antibodies to distinguish the eggs of the two species and thereby prevent overuse of the costly pesticides.

Small Business Innovation Research

Ocean Optics Inc., Dunedin, FL (Tel. 813-733-2447), showed its new line of miniature fiber optic spectrometers, developed with a Department of Energy SBIR grant, which emphasize versatility and low cost. The optical bench units measure just 7 x 5 x 2 cm, and their gratings, whether holographic or ruled, can scan light over a linear array of 1024 CCD detectors for analysis-grade performance. The system provides a PC interface and can be adapted for absorbance, transmittance, reflectance, or fluorescence spectroscopy. Eight configurations are available as are 12 gratings spanning the spectral range from ultraviolet to the near-infrared and including the deuterium, mercury/argon, tungsten, halogen, and xenon lines. Leeward Bean, Ocean Optics' president, said the spectrometers are unmatched in "size, cost, and the versatility and flexibility that come with using optical fiber to transmit the signals," which enhances the devices' capability to monitor samples in the field rather than in a distant laboratory. A new version featuring a lead sulfide detector that extends the spectral range to three microns is planned for introduction at the 1995 Pittsburgh Conference.

The US Marine Corps Systems Command, Quantico, VA (Tel. 703-640-2761), instituted its nylon heat-exchanger SBIR program in 1991. With the cooperation of DuPont Canada Inc. and Cesaroni Technology Inc., the program fabricated a nylon liquid-to-liquid or liquid-to-air exchanger that reduces weight by 50-70 percent, increases corrosion resistance, and improves the life-cycle cost over conventional metal heat exchangers. It could find application, according to Commander Joe Johnson of the Marine Corps Systems Command, in "all military and commercial vehicles where the need exists to eliminate the standard corrosive radiator."

The budworm (shown here) and bollworm cost US cotton growers more than $300 million per year.

Photo Clyde E. Morgan, USDA Agricultural Research Service

Quest Integrated Inc., Kent, WA (Tel. 206-872-9500), displayed its Euclid™ Intelligent Laser Alignment System Series 300. This laser alignment device, originally developed for the Air Force to line up ballistic test tracks, and supported by an SBIR grant, has been adapted for commercial use. Consisting of a precision alignment laser, two targets, a power supply, a bus cable, and a handheld pendant that can be custom-programmed for each measurement application, the device compensates fully for beam vibration, beam wander, and drift. The two targets, one transparent and one reflective, make a simple task of measuring lateral position by triangulation. Boeing is using the device to align fuselage sections of its 777 airliner for welding. According to Bob McCullough, vice president of Advanced Measurement Systems for Quest Integrated, "the Series 300 reduced alignment time from 60 hours apiece for three people down to three hours apiece for two."

From Aeronautics to Robotics

Sky Technologies, Hurst, TX (Tel. 817-282-7573), exhibited a life-size mock-up of its Aircar and showed a continuous videotape of scale-model test flights. With a wingspan of just ten feet, the Aircar is designed to operate on the road as well as in the air, without the operator having to make transitional adjustments to the wings as in earlier road/air machines. The roll and pitch instabilities resulting from the low aspect ratio of its stubby wings are compensated for by tail winglets. The company has tested the full-scale prototype in a wind tunnel and now seeks investors to carry the design into production. Initial commercial targets will include the military, law-enforcement agencies, and corporations that use business jets—with supercharging, the Aircar could fly up to 310 mph.

Jet Propulsion Laboratory's Robotics System and Advanced Computer Technology Section (Tel. 818-354-6543) demonstrated a modular autonomous robotic system (MARS) that converts any vehicle to autonomous control. It incorporates a modem open-system architecture, with ultrasonic and infrared sensors, a global positioning system, and control methods such as teleoperation and absolute and relative autonomous navigation. For routine autonomous patrolling of semi-structured environments, indoors or out, the MARS is designed to fulfill robotic vehicle needs such as environmental monitoring of refineries, site security, elimination of explosives and mines, intrafacility transport, and hazardous waste disposal.

Formerly one of the most complex nuclear weapons production facilities in the nation, the Savannah River Site exhibited technologies developed over decades in operating, maintaining, and restoring the site as a resource for US industry. The Savannah River Technology Center, operated by Westinghouse Savannah River Company, Aiken, SC (Tel. 803-644-6251), for the Department of Energy, consists of a technical library; chemical, robotics, environmental sciences, and instrument development laboratories; metallurgical facilities; shielded facilities; and machine and glass shops. Also at the site is the Savannah River Ecology Laboratory, operated by the University of Georgia, at which ground was broken recently for a 5000-sq-ft addition. Citing the total of 15 CRADAS and 83 licensing agreements that the site has achieved over the past five years, Vid Dekshenieks of the Economic Development Division singled out advantages to local industry. "We have asked three contractors to examine the site and recommend companies in Georgia and South Carolina that might utilize our technologies and do business with us," he said. The site's strengths lie in probes and sensors, robotics, and bioremediation, especially horizontal-well vitrification of hazardous wastes. Its new Defense Waste Processing Facility is the country's first for full-scale high-level radioactive waste vitrification. □

Omniview, a NASA-funded visual imaging system, earned TRI Inc., Knoxville, TN, a 1994 SBIR Technology of the Year Award. The technology expands video camera imaging by digitizing the image and manipulating it electronically. This replaces the standard mechanical camera operations of panning, zooming, tilting, and revolving with electronic analogues.

The award was established by the Technology Utilization Foundation last year to recognize important new technologies or products with strong commercial potential that were developed through the government's Small Business Innovation Research (SBIR) grant program. Awards were presented in November at the Technology Transfer Awards Dinner during the Technology 2004 conference and exhibition.

TRI set out to design a digital visual system that could handle multiple camera functions yet be less cumbersome than mechanical systems. NASA has used the system for research with robotic arms and in cryogenic wind tunnels. Since 1988, TRI has increased the processing speed and enhanced the images in the system as it prepared Omniview for commercial release.

The system uses a fish-eye lens to register the maximum amount of visual information in a room, then digitizes and processes that data. After removing the lens's distortion, it allows the user to focus on different parts of the visual field and perform operations upon that field such as panning across it or zooming in on details. Omniview also allows a breakdown of the image into four separate fields with different foci. Thus, by having one camera that takes in a large field-of-view, Omniview displaces the need for either multiple cameras or for the mechanical systems that pan, tilt, or revolve the camera and zoom the lens.

(Top) By digitizing images, the Omniview system permits the user to manipulate them—pan, zoom, and tilt—without moving the camera. (Bottom) Accepting the SBIR Technology of the Year Awards at Technology 2004 were, left to right: Robert S. Reis, president of Savi Technology; John Schewel, VP of marketing and sales, Virtual Computer Corp.; and Dr. H. Lee Martin, president, TRI Inc.

Photos TRI (top) and Robert L. Knudsen (bottom)

Applications extend into almost any area where video cameras are used. For security and surveillance, the system offers a small, simple camera that can be made virtually undetectable behind pinhole-sized openings. The camera doesn't move or make noise while providing security personnel a full-range view of an area. Another feature permits several cameras, which can be armed with alarms, to share the same monitor without hardwiring. Having just one monitor reduces the chance for human error, as when a guard overlooks a clue appearing on one of many monitors.

The system also can assist in endoscopic surgery, noninvasive procedures that normally require a set of probes inserted into the patient, with miniature mechanisms for panning or tilting to obtain different perspectives within an organ. Omniview gives the surgeon wide-angle and close-up views with only one camera-probe insertion and without having to change the camera position.

For videoconferences, TRI's system eliminates the on-site camera operator. Conferees can carry on their business without the unnatural distraction of a camera suddenly moving up to their faces or making noises. The end-user, who may be thousands of miles away, can silently control the image, selecting whom or what in the conference to focus on at any one time. The system also allows the entire field-of-view to be stored so that different users can focus on various parts of the conference later.

TRI has contracted with Benthos Inc. of North Falmouth, MA, to offer a line of underwater Omniview cameras. The system's freedom from movement can ease the viewing of very tight spots, such as inside shipwrecks or underwater caves, while the wide viewing angle can help minimize distortion from water movement or aquatic life.

Other potential uses include home entertainment, enabling a television viewer to select different views of the televised image. As a teaching tool, Omniview can allow students more interaction with the material. As in underwater work, the system can eliminate mechanical camera movement in the very tight and harsh environments within pipelines to inspect for cracks and leaks.

For more information about the technology described in this article, contact: TRI Inc. 7325 Oak Ridge Highway, Knoxville, TN 37931. Tel: 615-690-5600; Fax: 615-690-2913.

TRI garnered one of three inaugural SBIR Technology of the Year Awards. The other grand winners were:

Savi Technology of Mountain View, CA, devised a way to keep track of a large number of items automatically through radio tagging. SaviTag™, a device the size of a card deck that contains a radio transmitter/receiver and a computer, is attached to each item to be identified and located. It sends signals to the Interrogator, which then relays data from all radio tags in the system to a central console that displays a map.

While earlier identification systems require a manual search before assets can be identified, the Savi system requires no such human intervention. Thousands of individual items can be identified using a single system. Working at a central computer, the user clicks on the icon representing the desired item. The item's location then appears on the console map. The central computer holds a large database that links tag identifications with data about the items. Additional attachments provide further information: the SensorTag measures and records temperature

New Product Ideas

New Product Ideas are just a few of the many innovations described in this issue of *NASA Tech Briefs* and having promising commercial applications. Each is discussed further on the referenced page in the appropriate section in this issue. If you are interested in developing a product from these or other NASA innovations, you can receive further technical information by requesting the TSP referenced at the end of the full-length article or by writing the Technology Utilization Office of the sponsoring NASA center (see page 20). NASA's patent-licensing program to encourage commercial development is described on page 20.

Poly(arylene ether)s Containing Pendent Ethynyl Groups

Cross-linked molecular structures are formed that show greater resistance to solvents and higher glass-transition temperatures and tensile moduli. These polymers are useful as adhesives, moldings, films, and matrices of composite materials.
(See page 62.)

Storing Data in Circulating Electrons

A proposed device would contain electrons traveling in a circular orbit in a vacuum. Such devices are theoretically capable of storing 446 gigabytes of data per meter of circumference of the orbit.
(See page 38.)

Enhancing Images by Nonlinear Extrapolation in Frequency

In comparison with other edge-enhancement methods, this method is computationally simpler and yields better results.
(See page 95.)

Litter-Spinning Retarders

Basket litters used to hoist injured people into helicopters would be equipped with vertical plates on their undersides to prevent spinning. This improvement will simplify evacuation of the injured.
(See page 85.)

Beat-Frequency/ Microsphere Medical Ultrasonic Imaging

This imaging system is sensitive enough to yield readings of blood flow in the heart even when the microspheres, used as ultrasonic contrast agents, are injected far from the heart.
(See page 97.)

Artificial Soil With Built-in Plant Nutrients

An artificial soil provides nutrients to plants during several growing seasons without the need to add fertilizer or a nutrient solution.
(See page 98.)

and humidity while the UniTruck detects the items' motion, access, and yard location.

Applications run to any situation where items need to be located. The inventor, Robert S. Reis, conceived the idea for TagAlong, the system's first incarnation, when he needed to keep track of his very active child. The military has used SaviTags to keep track of parts for jet engines receiving overhauls and to locate containers or vehicles in Army ports. A freight transporter uses the system for security, with automatic truck identification and unlocking, and tamper-resistant sensors for rail cars, trailers, and on-board containers.

Virtual Computer Corporation (VCC), Reseda, CA, developed its award-winning Virtual Computer™ for the US Naval Surface Warfare Department in 1991. The device is one of a new class of computing machine called reconfigurable hardware. This class employs massively reconfigurable, or programmable, logic, blurring the line between hardware and software.

The technology solves the problem of Amdahl's law, which limits performance improvements on hardware scale-ups: doubling the number of processors always provides less than double the system's throughput. This law kicks in when a designer attempts to halve an algorithm's running time by dividing a problem in two and running the two parts in parallel. Since one part of the problem is invariably longer than the other, there is always a delay as one processor waits for the other to finish. But reconfiguring the hardware to make it fit the algorithm allows all the dependent processors to be coalesced into a single processor. This overcomes Amdahl's law and speeds up processing.

A new generation of chips makes reconfiguring possible. The field-programmable gate array (FPGA) has a large number of potential connections between its gates—and the programmer can make or break connections. Thus, instead of having hardware specifically designed for an application, the software essentially designs the hardware it needs. Downloading the file rearranges the logic to implement the hardware design.

Such a technology can be useful in any supercomputing application. In a DNA sequencing application, an FPGA-based coprocessor at Maryland's Supercomputing Research Center beat a Cray-2 by a factor of 330. An Apple Computer project using four FPGA chips stumped a Cray on a video-compression algorithm.

The Virtual Computer promises to make supercomputer performance affordable on desktop workstations. VCC now offers two versions of its product. The full version, made for the Navy and costing $150,000, runs on VHSIC Hardware Description Language. It comes in four configurations, with 14 to 52 FPGAs providing 182,000 to 676,000 reconfigurable gates. The company recently introduced a scaled-down, $10,000 model called the Engineer's Virtual Computer (EVC1), which is a plug-in SBus-based board for implementing logical, mathematical, and other computational operations. Each has a single FPGA with 10,000 or 13,000 reconfigurable gates. All versions can be reconfigured in 250 milliseconds or less.

For more information about the 1995 SBIR Technology of the Year competition, contact Wayne Pierce, Technology Utilization Foundation, 41 East 42nd St., Suite 921, New York, NY 10017. Tel: 212-490-3999; Fax: 212-986-7864.

NASA Commercial Technology Team

NASA's R&D efforts produce a robust supply of promising technologies with applications in many industries. A key mechanism in identifying commercial applications for this technology is NASA's national network of commercial technology organizations. The network includes ten NASA field centers, six Regional Technology Transfer Centers (RTTCs), the National Technology Transfer Center (NTTC), business support organizations, and a full tie-in with the Federal Laboratory Consortium (FLC). We encourage all businesses with technical needs to contact the appropriate organizations for more information. For those who have access to the Internet, general information can be accessed with Mosaic software on the NASA Commercial Technology Home Page at URL: http://nctn.oact.hq.nasa.gov. Instructions regarding how to acquire the free Mosaic software can be obtained by sending an e-mail request to: innovation@oact.hq.nasa.gov.

NASA's Technology Sources

If you need further information about new technologies presented in *NASA Tech Briefs*, request the Technical Support Package (TSP) indicated at the end of the brief. If a TSP is not available, the Commercial Technology Office at the NASA field center that sponsored the research can provide you with additional information and, if applicable, refer you to the innovator(s). These centers are the source of all NASA-developed technology.

Ames Research Center
Selected technological strengths: Fluid Dynamics; Life Sciences; Earth and Atmospheric Sciences; Information, Communications, and Intelligent Systems; Human Factors.
Syed Shariq
(415) 604-0753
syed_shariq@qmgate.arc.nasa.gov

Dryden Flight Research Center
Selected technological strengths: Aerodynamics; Aeronautics Flight Testing; Aeropropulsion; Flight Systems; Thermal Testing; Integrated Systems Test and Validation.
Lee Duke
(805) 258-3119
duke@louie.dfrf.nasa.gov

Goddard Space Flight Center
Selected technological strengths: Earth and Planetary Science Missions; LIDAR; Cryogenic Systems; Tracking; Telemetry; Command.
George Alcorn
(301) 286-5810
galcorn@gsfc-mail.nasa.gov

Jet Propulsion Laboratory
Selected technological strengths: Near/Deep-Space Mission Engineering; Microspacecraft; Space Communications; Information Systems; Remote Sensing; Robotics.
William Spuck
(818) 354-3528
william_h_spuck@jpl.nasa.gov

Johnson Space Center
Selected technological strengths: Artificial Intelligence and Human Computer Interface; Life Sciences; Human Space Flight Operations; Avionics; Sensors; Communications.
Hank Davis
(713) 483-0474
hdavis@profs.jsc.-nasa.gov

Kennedy Space Center
Selected technological strengths: Emissions and Contamination Monitoring; Sensors; Corrosion Protection; Bio-Sciences.
Bill Sheehan
(407) 867-2544
billsheehan@ksc.nasa.gov

Langley Research Center
Selected technological strengths: Aerodynamics; Flight Systems; Materials; Structures; Sensors; Measurements; Information Sciences.
Charlie Blankenship
(804) 864-6005
c.p.blankenship@larc.nasa.gov

Lewis Research Center
Selected technological strengths: Aeropropulsion; Communications; Energy Technology; High Temperature Materials Research.
Walter Kim
(216) 433-3742
wskim@lims01.lerc.nasa.gov

Marshall Space Flight Center
Selected technological strengths: Materials; Manufacturing; Nondestructive Evaluation; Biotechnology; Space Propulsion; Controls and Dynamics; Structures; Microgravity Processing.
Harry Craft
(205) 544-5419
harry.craft@msfc.nasa.gov

Stennis Space Center
Selected technological strengths: Propulsion Systems; Test/Monitoring; Remote Sensing; Nonintrusive Instrumentation.
Lon Miller
(601) 688-1632
lmiller@ssc.nasa.gov

NASA-Sponsored Commercial Technology Organizations

These organizations were established to provide rapid access to NASA and other federal R&D and foster collaboration between public and private sector organizations. They also can direct you to the appropriate point of contact within the Federal Laboratory Consortium.

Lee Rivers
National Technology Transfer Center
(800) 678-6882

Robert Stark
Far-West Technology Transfer Center
University of Southern California
(800) 472-6785 or
(213) 743-6132

Dr. William Gasko
Center for Technology Commercialization
Massachusetts Technology Park
(800) 472-6785 or
(508) 870-0042

J. Ronald Thornton
Southern Technology Applications Center
University of Florida
(800) 472-6785 or
(904) 462-3913

Gary Sera
Mid-Continent Technology Transfer Center
Texas A&M University
(800) 472-6785 or
(409) 845-8762

Lani S. Hummel
Mid-Atlantic Technology Applications Center
University of Pittsburgh
(800) 472-6785 or
(412) 648-7000

Chris Coburn
Great Lakes Technology Transfer Center
Battelle Memorial Institute
(800) 472-6785 or
(216) 734-0094

Easy Access To The FLC: Call (206) 683-1005 for the name of the Federal Laboratory Consortium Regional Coordinator in your area. The Regional Coordinator, working with the FLC Locator, can help you locate a specific laboratory to respond to your needs.

NASA Program Offices

At NASA Headquarters there are seven major program offices that develop and oversee technology projects of potential interest to industry. The street address for these strategic business units is: NASA Headquarters, 300 E St. SW, Washington, DC 20546.

Gene Pawlik
Small Business Innovation Research Program (SBIR)
(202) 358-4661
gpawlik@oact.hq.nasa.gov

Robert Norwood
Office of Space Access and Technology (Code X)
(202) 358-2320
rnorwood@oact.hq.nasa.gov

Philip Hodge
Office of Space Flight (Code M)
(202) 358-1417
phodge@osfms1.hq.nasa.gov

Gerald Johnson
Office of Aeronautics (Code R)
(202) 358-4711
g_johnson@aeromail.hq.nasa.gov

Bill Smith
Office of Space Sciences (Code S)
(202) 358-2473
wsmith@sm.ms.ossa.hq.nasa.gov

Bert Hansen
Office of Microgravity Science Applications (Code U)
(202) 358-1958
bhansen@gm.olmsa.hq.nasa.gov

Granville Paules
Office of Mission to Planet Earth (Code Y)
(202) 358-0706
gpaules@mtpe.hq.nasa.gov

NASA's Business Facilitators

NASA has established several organizations whose objectives are to establish joint sponsored research agreements and incubate small start-up companies with significant business promise.

Dr. Stephen Gomes
American Technology Initiative
Menlo Park, CA
(415) 325-5353

Jill Fabricant
Johnson Technology Commercialization Center
Houston, TX
(713) 335-1200

John Gee
Ames Technology Commercialization Center
Sunnyvale, CA
(408) 734-4700

Dan Morrison
Mississippi Enterprise for Technology
Stennis Space Center, MS
(800) 746-4699

If you are interested in information, applications, and services relating to satellite and aerial data for Earth resources, contact: Dr. Stan Morain, **Earth Analysis Center,** (505) 277-3622.
For software developed with NASA funding, contact **NASA's Computer Software Management and Information Center (COSMIC)** at (706) 542-3265, fax (706) 542-4807.
If you have a questions...**NASA's Center for AeroSpace Information** can answer questions about NASA's Commercial Technology Network and its services and documents. Use the Feedback Card in this issue or call (410) 859-5300, ext. 245.

Improved, Easier-To-Use Tunneling Infrared Sensors

Deflection voltages are reduced, and thermal drifts are eliminated.

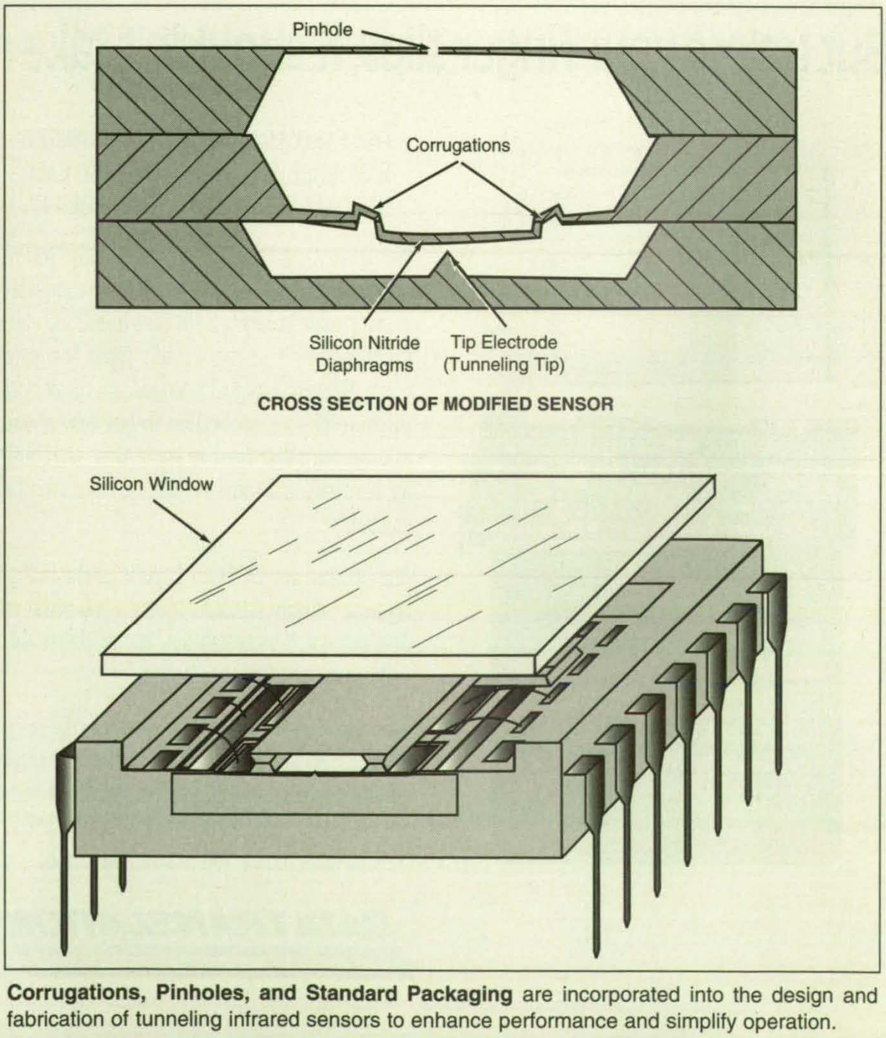
NASA's Jet Propulsion Laboratory, Pasadena, California

Designs of electron-tunneling infrared sensors and micromachining processes used to fabricate them have been modified to increase sensitivity and to simplify operation, adjustment, and associated circuitry. The performances of the modified sensors exceed those of other commercially available, uncooled infrared sensors. Operation of the sensors has been simplified to such an extent that it is now feasible to ship them to nonexpert users for routine testing and evaluation in their laboratories.

The principles of operation and construction of electron-tunneling infrared sensors have been described in several previous articles in NASA Tech Briefs. To recapitulate: these are pneumatic/thermal infrared detectors that can operate at ambient temperature. They are fabricated by techniques like those used to make integrated circuits and discrete microelectronic devices. They are modern successors to the Golay cell, in which the infrared radiation heats a trapped gas, causing the gas to expand and displace a diaphragm. In this case, the displacement of a silicon nitride diaphragm is sensed by quantum-mechanical tunneling of electrons between an electrode deposited on the diaphragm and a nearby tip electrode as in an electron-tunneling microscope. Also as in a tunneling microscope, the tunneling current serves as a feedback signal, which is used to generate large voltages that are applied to electrostatic-deflection electrodes to control the displacement of the diaphragm. Thus, the deflection voltage needed to maintain a constant displacement is a measure of the absorbed infrared power.

The modifications incorporated into the present generation of tunneling infrared sensors were made in response to observations of several undesired characteristics in several earlier generations of prototypes. These characteristics and the corresponding modifications were as follows:

- The silicon nitride diaphragms in the older sensors were flat. The stiffnesses of these diaphragms increased sharply with deflection, over the required deflection range of 3 to 5 μm, from 1.5 N/m to more than 100 N/m. As a result, complicated clamping structures were needed to reduce the gap between the diaphragm and tip electrodes, and deflection voltages > 400 V were needed. In response, the silicon nitride diaphragms were modified to include corrugations (see figure), by use of a combination of photolithography, chemical vapor deposition, and chemical etching. The corrugations delay the onset of the increase in stiffness to such an extent that mechanical clamping to control the gap can be simplified greatly and deflection voltages can now be £ 150 V. The lowering of deflection voltages enables simplification of the feedback circuitry.
- Fluctuations in ambient temperatures caused fluctuations in the pressures of the trapped gases, with consequent need to adjust clamps and with rapid drifts in required deflection voltages (or equivalently, in sensor outputs) during normal operation. The remedy was simply to add 0.5-μm-diameter pinholes to allow just enough leakage so that the pressure in the trapped gas can equilibrate with



Corrugations, Pinholes, and Standard Packaging are incorporated into the design and fabrication of tunneling infrared sensors to enhance performance and simplify operation.

the pressure in the surrounding gas within a time that is acceptably short (e.g., 1 second) yet long enough to permit detection of radiation-induced pressure fluctuations at frequencies typically > 5 Hz. The pinholes are fabricated in silicon nitride diaphragms by electron-beam lithography and reactive-ion etching. The operating voltages of tunneling sensors equipped with pinholes were found not to drift with changes in ambient temperature. Furthermore, it was found that clamping structures could be eliminated entirely in favor of completely bonded structures within standard integrated-circuit carriers.

- Tunneling electrodes were positioned outside the trapped gas and exposed to ambient air, where they were subject to contamination. Also, the sensors responded to sound. The remedy for both of these undesired characteristics was to seal the sensor structure, along with its own atmosphere of clean air, into an integrated-circuit package equipped with a silicon window. The silicon window is transparent to the infrared radiation to be detected and is mechanically stiff enough to suppress acoustic coupling to the sensor.

This work was done by Richard E. Muller, Paul D. Maker, Erika C. Vote, William J. Kaiser, Thomas W. Kenny, and Judith A. Podosek of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 57*** *on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

William T. Callaghan, Manager
Technology Commercialization
JPL-301-350
4800 Oak Grove Drive
Pasadena, CA 91109

Refer to NPO-19087, volume and number of this NASA Tech Briefs issue, and the page number.

Capacitive Sensing of Gaseous Fraction in Two-Phase Flow

This instrument works even with liquids that have relatively low permittivities.

Lewis Research Center, Cleveland, Ohio

An instrument under development makes nonintrusive, real-time capacitive measurements to determine the volume fraction of vapor or other gas in a flowing, electrically nonconductive liquid/gas mixture. When fully developed, the instrument will be especially useful for measuring the proportions of vapor in boiling, condensing, and flowing heat-transfer fluids and in cryogenic fluids.

The instrument includes electrodes mounted in the pipe wall, plus circuitry that measures the capacitances between selected electrodes. Because the permittivities of the liquid and gas are different, the capacitances vary with the size and number of gas bubbles in the liquid. Thus, the volume fraction of gas can be computed from the measured capacitances by use of theoretical predictions and/or empirical calibration data.

The basic principle of capacitive measurement of gaseous fraction, as described thus far, is not new; the principle has been applied to liquids that have relatively high permittivities (e.g., water), such that range of measured capacitances is about 50 times that for liquids that have relatively low permittivities (e.g., chlorofluorocarbons). What is new in this instrument is its specific design, which maximizes sensitivity in different ranges of volume fractions and provides for accurate measurements of the capacitances over the small range (ª1 pF for typical pipe and electrode dimensions) between all-vapor and all-liquid flow.

There are 24 electrodes wrapped in a spiral pattern around the pipe along a length of 6 to 12 pipe diameters. Each electrode makes a complete turn around the pipe in a length of 6 diameters. At any cross section, each electrode occupies about 15° of the total 360° circumference. This arrangement of electrodes is fixed, but the connections between the electrodes and the associated signal-generating and signal-processing circuits can be switched electronically to configure the electric field and the circuits for maximum sensitivity in the actual flow regime.

Figure 1 shows the two principal configurations. The "macroscale" configuration provides for measurement of the average gaseous volume fraction across the pipe and yields greatest sensitivity at low gaseous volume fraction. At large gaseous volume fraction, the flow pattern becomes annular, with gas filling the middle and liquid in a thin film on the wall of the pipe: in this regime, the sensitivity of the "macroscale" configuration is reduced, and the gaseous volume fraction can be resolved better by use of the "microscale" configuration. In slug flow, regions of bubbly and annular flow alternate: the "macroscale" configuration is well suited for detecting the passage of liquid slugs in that measured capacitances are highest when the cross section of the pipe is filled mostly with liquid and lowest when it is filled mostly with gas.

The associated electronic circuitry (see Figure 2) includes a signal generator which puts out a tightly controlled triangular voltage waveform that alternates between +10 V and −10 V at a frequency of 50 kHz. This signal is applied to the

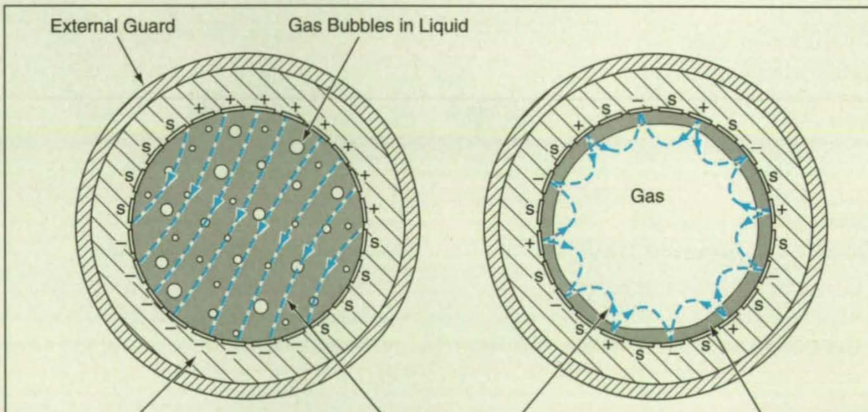


Figure 1. **Each Electrode Can Be Switched Electronically** to connect it to the measurement-signal source (+), as a sensing electrode (−), or to a grounded shield (s). The pattern of connections is selected to optimize the measurements of capacitance in the actual flow regime.

electrodes to obtain currents directly proportional to the capacitances. Signal-processing circuits convert the current signals to analog output voltages proportional to the capacitances. The design minimizes the effect of the capacitances of the cables that connect the electronic circuits to the electrodes and provides a nulling capability to maximize sensitivity.

Feasibility was demonstrated with a prototype sensor that consisted of electrodes about 10 diameters long in a pipe of about 19-mm diameter. Calibration was performed under simulated static flow conditions by use of low-permittivity plastic inserts. The instrument exhibited low noise, good range of output, and good dynamic response when tested with the pipe oriented vertically, using a flow of vacuum-pump fluid containing air bubbles.

This work was done by Christopher J. Crowley and Michael K. Sahm of Creare, Inc., for **Lewis Research Center.** *For further information,* ***write in 189*** *on the TSP Request Card.*
LEW-15607

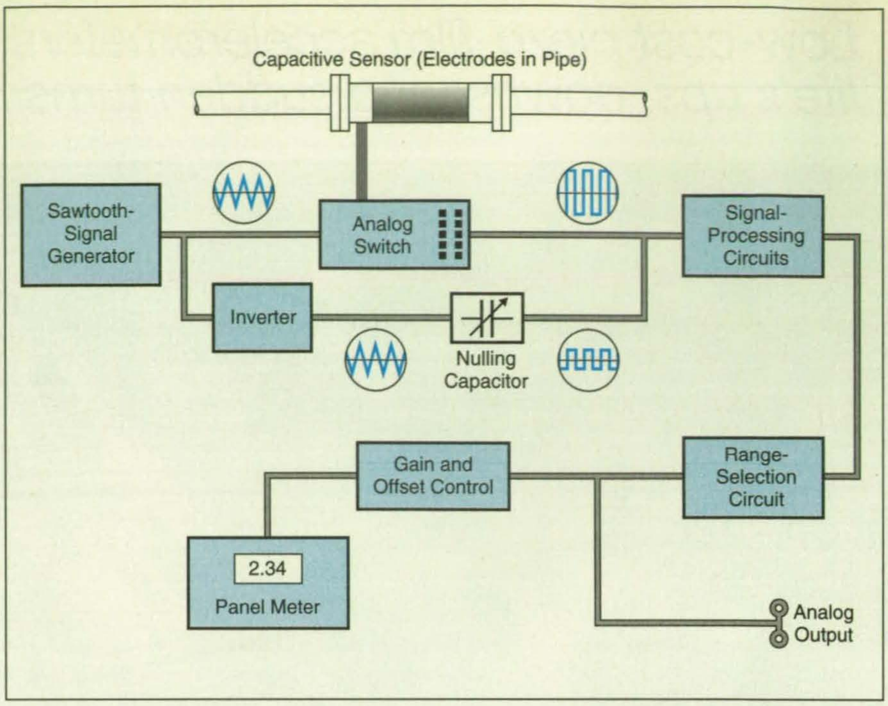


Figure 2. This **Package of Electronic Circuits** measures the capacitances between electrodes and processes the measurements into an output voltage related to the volume fraction of gas in the liquid in the pipe.

Bolt-Tension Sensor

Force on a magnetostrictive washer under the bolthead changes the inductance in a sensing circuit.

Lyndon B. Johnson Space Center, Houston, Texas

In a developmental technique for measuring the tensile force of a bolt, a specially fabricated magnetostrictive washer is used as a force transducer. A compact, portable inductive electronic sensor is placed against the washer to measure the tension force. The new system is expected to provide an accurate, economical, and convenient way to measure bolt tension in the field. Measurements on a test assembly show promise that the tension can be measured to an accuracy of about ±1 percent of the load capacity of a typical bolt.

With respect to the function of the bolt-tension sensor, magnetostrictive materials can be classified as positive or negative. The magnetic permeability of a positive magnetostrictive material decreases with compressive stress applied parallel to a magnetic field, while that of a negative magnetostrictive material decreases with compressive stress applied perpendicular to the magnetic field. Figure 1 shows one version of the bolt-tension sensor based on a negative magnetostrictive material. The magnetostrictive washer (more accurately, a washerlike assembly) is placed between the load-bearing surface and the bolthead. The assembly includes two approximately-crescent-shaped pieces of the negative magnetostrictive material sandwiched between layers of nonmagnetic stainless steel (not shown) to reduce leakage of magnetic flux into the bolt and the surrounding joint structure and to distribute the large bearing loads.

The pieces of magnetostrictive material are positioned so that magnetic cores of sensing coils can be clamped into contact with them: This establishes a magnetic circuit that includes the magnetostrictive material, in which the magnetic field is perpendicular to any compressive stress that might be applied by the bolt. The compressive stress produced by tightening the bolt reduces the magnetic permeability of the magnetostrictive material, thereby reducing the inductance of the sensing coil in the magnetic circuit.

In experiments, some of the best results were obtained by use of prototype sensors containing nickel, which is a negative magnetostrictive material. It was also found that to achieve the dimensional stability required for repeat-

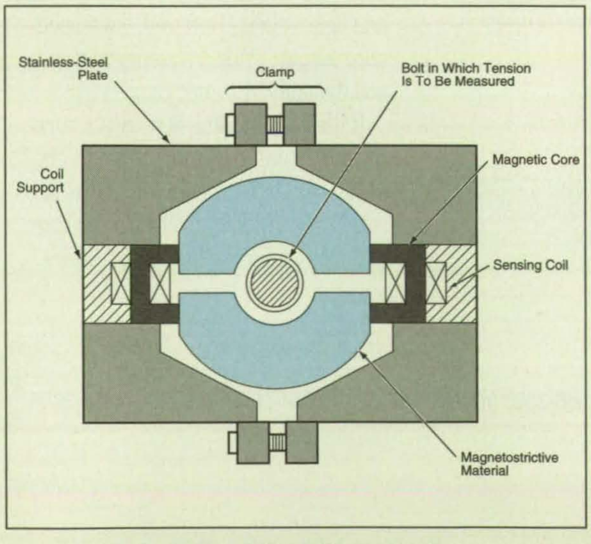


Figure 1. In this **Bolt-Tension Sensor**, two halves of the magnetic core of the sensing coil make contact with opposite ends of two crescent-shaped pieces of magnetostrictive material, which constitute a washerlike transducer assembly. Tension in the bolt causes a change in the inductance of the sensing coil. The washerlike transducer assembly resembles a regular flat washer and can remain under the bolthead permanently. Bolt tension can thus be monitored continuously, or the sensing coil can be moved to measure tension In various bolts.

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able results, the magnetic and nonmagnetic portions of the washer assembly should be permanently bonded together. The various contact surfaces of the washer, the bolt, the load bearing surface, and the sensing coil should come into intimate contact upon assembly without application of force. These conditions were not fully met in the prototype sensors, partly because they included stacks of separate components. Thus, some deformation of the contact faces took place during the first load cycle in each series of measurements. That is believed to account for the differences in results between the first and subsequent load cycles (see Figure 2).

Further development work could focus on optimization of the configuration of the magnetostrictive washer, optimization of the interface between the washer and the sensing coil, and optimization of the inductance-measuring circuitry that is connected to the sensing coil.

This work was done by James H. Goldie, Dariusz A. Bushko, and Michael J. Gerver of SatCon Technology Corp. for **Johnson Space Center.** *For further information,* ***write in 174*** *on the TSP Request Card.*
MSC-21948

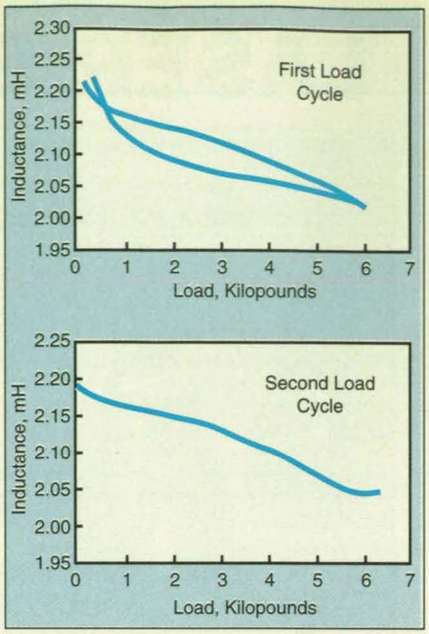


Figure 2. These **Measurements of Inductance vs. Bolt Tension** were made with a prototype bolt-tension sensor containing nickel as the negative magnetostrictive material. The measurements taken on the second and subsequent load cycles were highly) repeatable. The inductance measurements were made with an impedance bridge operating at a frequency of 100 Hz.

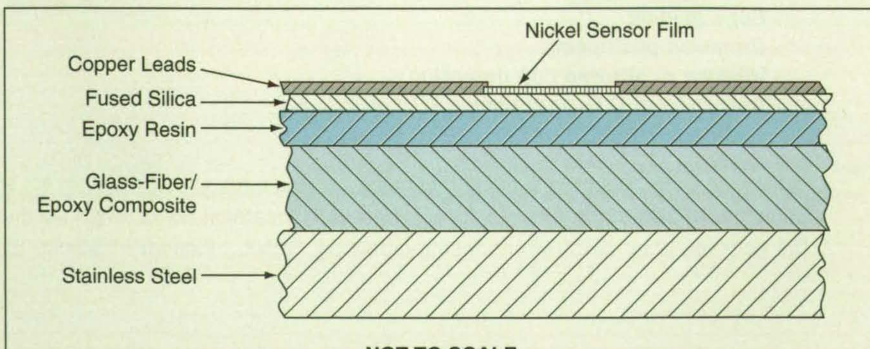
Deposition of Thin-Film Sensors on Glass-Fiber/Epoxy Models

The surfaces are bombarded with ions to promote adhesion of deposits.

Langley Research Center, Hampton, Virginia

A direct-deposition process has been devised for the fabrication of thin-film sensors on the three-dimensional, curved surfaces of models that are made of stainless steel covered with glass-fiber/epoxy-matrix composite material (see figure). The models are used under cryogenic conditions, and the sensors are used to detect on-line transitions between laminar and turbulent flows in wind tunnel environments. The sensors fabricated by this process can be used at temperatures from -300 °F (about -184 °C) to 175 °F (about 79 °C).

The process includes several steps in which the surface of the model is first



The **Thin-Film Sensor** is deposited directly on the surface of the model to provide relatively nonintrusive measurements indicative of transitions between laminar and turbulent flows.

bombarded with an ion beam source in preparation for the materials about to be deposited. While the surface is bombarded with an ion beam, an electron beam source is activated so that a layer of fused silica is vapor-deposited to a total desired thickness value (typically, 1 micron or 10,000 Å). The layer of fused silica serves as a surface stabilization layer for the next step.

A metal mask with an aperture in the specified pattern of the sensor film is placed on the surface at the specified sensor location. The surface area exposed through the mask is cleaned by ion-beam bombardment for a predetermined time. Then as the bombardment continues, a metal (typically, nickel, platinum, and/or palladium) is vapor-deposited through the mask from the electron-beam source to form the sensor film. Deposition is continued until the thickness of the film reaches the value specified in the particular sensor design. A representative value for a nickel sensor film is 2,500 Å.

Next, a pattern for thin film leads is defined by taping directly on the surface of the model with Kapton (or equivalent) polyimide tape. The thin film leads are fabricated by a combination of ion-beam bombardment and electron-beam vapor deposition like that used to deposit the sensor film. The metal vapor-deposited in this step is typically copper, gold, or aluminum. A typical thickness for copper leads on the nickel sensor film described above is about 10,000 Å.

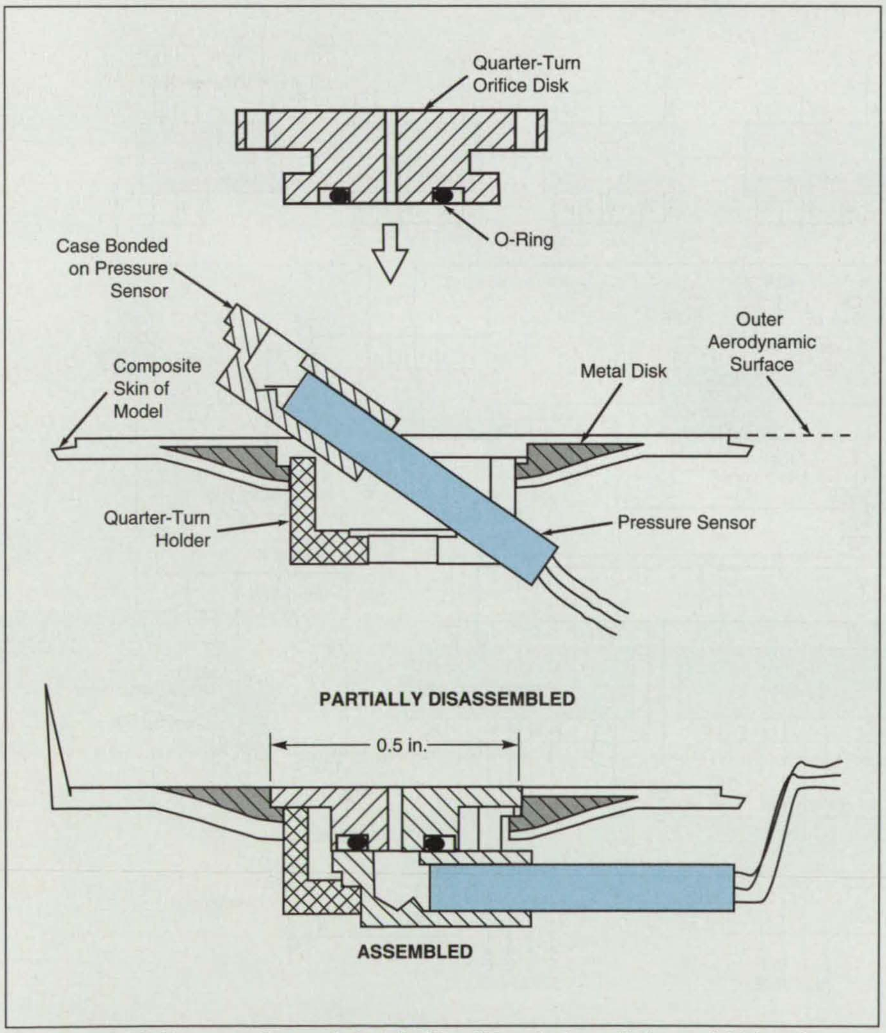
This work was done by Sang Q. Tran of **Langley Research Center.** *No further documentation is available.*
LAR-14591

Fixture for Mounting a Pressure Sensor

The pressure sensor can be removed from a model without dismantling the model.

Langley Research Center, Hampton, Virginia

A fixture for mounting a pressure sensor in an aerodynamic model simplifies the task of removal and replacement of the sensor in the event that the sensor becomes damaged. The fixture makes it unnecessary to dismantle the model. It also minimizes any change in the aerodynamic characteristics of the model in the event of replacement. Heretofore, replacement of pressure sensors usually necessitated dismantling of models, often with consequent modification of aerodynamic characteristics.



The **Removable Pressure Sensor** is installed in a fixture in the wall of a model. The wires from the sensor pass through a channel under the surface.

The fixture is incorporated into the outer wall of the model, which is typically made of a fiber-reinforced composite material. A hole is drilled and countersunk in the disk to accommodate the rest of the sensor-mounting hardware (see figure). The disk strengthens the wall at the hole site. A quarter-turn holder, designed to mate with a case on the pressure sensor, is permanently bonded with epoxy in the hole. The pressure sensor, in its case, is inserted through the hole and seated in the quarter-turn holder.

A quarter-turn orifice disk is inserted in the hole and rotated 90° into position by use of a spanner-type tool. The outer surface of the orifice disk is machined and/ or hand-worked so that when installation is complete, the outer surface of the orifice blends in with the surrounding aerodynamic surface of the model. An O-ring between the orifice disk and the sensor case seals the enclosure. The sensor communicates with the exterior through the orifice.

To replace a pressure sensor, a technician removes the orifice disk by use of the spanner tool, removes the faulty sensor, and inserts a working sensor in the hole. The technician then installs the orifice disk as before.

This work was done by Christopher M. Cagle of **Langley Research Center.** *No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-15070.

Electronic Components and Circuits

Digital Pulse-Width-Modulation Circuit

Pulse durations can be set at ≥ 1 μs, repeating at a rate of 1 kHz.

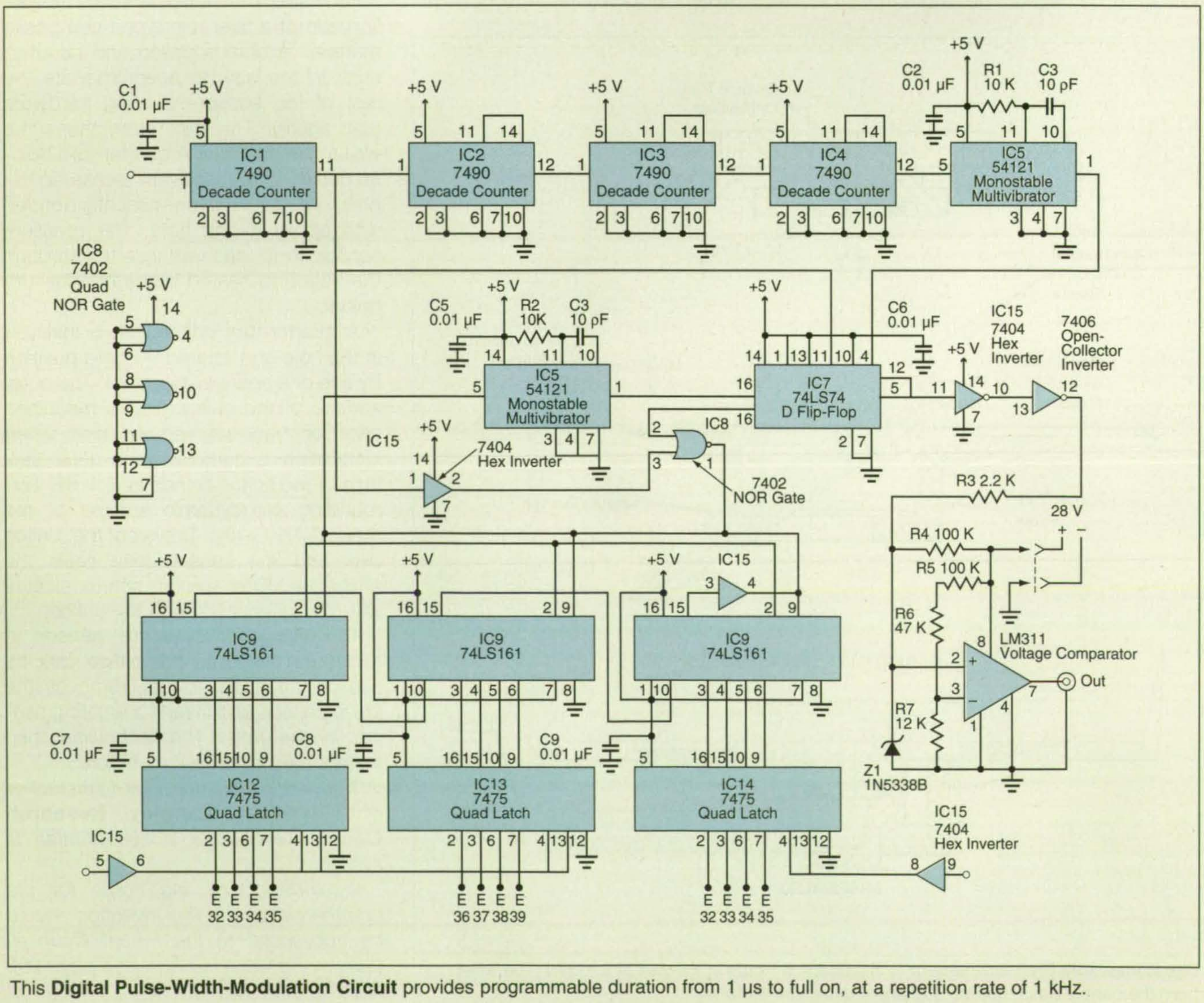
Lewis Research Center, Cleveland, Ohio

The figure shows a digital pulse-width-modulation circuit. Designed for use in controlling a CO_2 laser, the circuit can also be used in other applications in which the precision and flexibility of digital control of pulse durations are needed.

The circuit incorporates low-power Schottky transistor/transistor-logic (TTL) devices in critical high-speed parts. The circuit was designed in TTL to make it compatible with the Pro-Log 7914 (or equivalent) decoded input/output (I/O) utility printed-circuit card. (The 7914 circuit card was designed for use in development and testing of prototypes of I/O circuitry.) The 7914 circuit card provides STD-bus buffering and I/O-port-select decoding. The STD bus provides 8-bit data words and a 5-MHz clock signal.

The 5-MHz clock signal is converted to a 1-MHz signal by a 7490 decade counter configured to divide by 5. The 1-MHz signal is sent, via a clock synchronizer, to a three-stage binary divider that consists of three cascaded 74LS161 binary dividers. The synchronizer consists of a 74LS74 D flip-flop, a 7404 inverter gate, and a 7402 NOR gate. The dividers are programmed from the STD bus by means of three 7475 quad latches: this makes it possible to program the frequency division from 1 to 4,096 (12 bits).

The 1-MHz signal is also divided by 1,000 by use of three cascaded 7490 decade counters, each configured to divide by 10: this provides a 1-kHz signal, which is sent to a 54121 monostable multivibrator configured to provide a 0.1-μs pulse. The 0.1-μs pulse,



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repeated at 1 kHz, is used to set the 74LS74 D flip-flop. The flip-flop is reset by the three-stage binary divider via another 54121 monostable multivibrator configured to provide a 0.1-μs pulse: this results in a 1-kHz signal with a duration, in units of microseconds, equal to the reciprocal of the divisor of the three-stage binary counter. Thus, the signal is programmable with a pulse duration from 1 μs to full on with a repetition rate of 1 kHz. This signal is sent to a 7406 open-collector inverter via a 7404 inverter. The output is compatible with the 28-Vdc radio-frequency power supply of the laser. The interconnections among the various circuits (including this circuit) of the laser-control system are made via shielded or coaxial cable wherever possible to minimize radiated electromagnetic interference.

This work was done by Carl J. Wenzler and Dennis J. Eichenberg of **Lewis Research Center.** *Further information may be found in NASA TM-103112 [N90-28833/TB], "Design of a CO_2 Laser Power Control System for a Spacelab Microgravity Experiment."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, Linthicum Heights, Maryland, Telephone No. (301) 621-0394. Rush orders may be placed for an extra fee by calling the same number.

LEW-16046

Electronic Compensation for Distortion of Antenna Reflector

Amplitudes and phases of feeds would be adjusted to approximate a desired radiation field.

Langley Research Center, Hampton, Virginia

A proposed method of obtaining approximately the desired radiation or reception pattern from an antenna that includes a reflector is based on the well-known concept of superposition of electromagnetic fields generated by multiple feedhorns or feed antenna elements arrayed at various positions near the reflector and excited at electronically adjustable magnitudes and phases. In the original intended application, the reflector would be nominally paraboloidal, the feed elements would be *N* feedhorns in a hexagonal array, and the method would be used to compensate for deviations of the real reflector surface from the nominal paraboloidal shape. Clearly, the method and concept are also applicable to electronic beam steering and electronic antenna compensation in other situations.

The basic principle of the method is well known, and closely related methods have been described in a number of articles in *NASA Tech Briefs*. The desired near or far radiation field at Cartesian coordinates x,y in a specified near or far plane is represented by the complex amplitude $F(x,y)$, and the near or far radiation field produced by excitation of the nth feed element alone is represented by $A_nf(x,y)$, where $f(x,y)$ gives the spatial dependence and A_n is a complex amplitude that represents the adjustable magnitude and phase of the excitation.

The adjustable amplitudes would be chosen to make the total radiation field

$$\sum_{n=1}^{N} A_n f_n(x,y)$$

generated by all the feed elements equal a least-squares approximation to the desired field at a number of specified points x_i, y_i $(i = 1, 2 \ldots I)$. That is, one would choose A_n to obtain

$$\sum_{n=1}^{N} A_n f_n(x_i,y_i) \approx F(x_i,y_i)$$

for all *i*. The least-squares condition yields *N* simultaneous equations that are linear in the complex amplitudes and can be solved for these amplitudes by standard techniques.

The method has been tested thus far

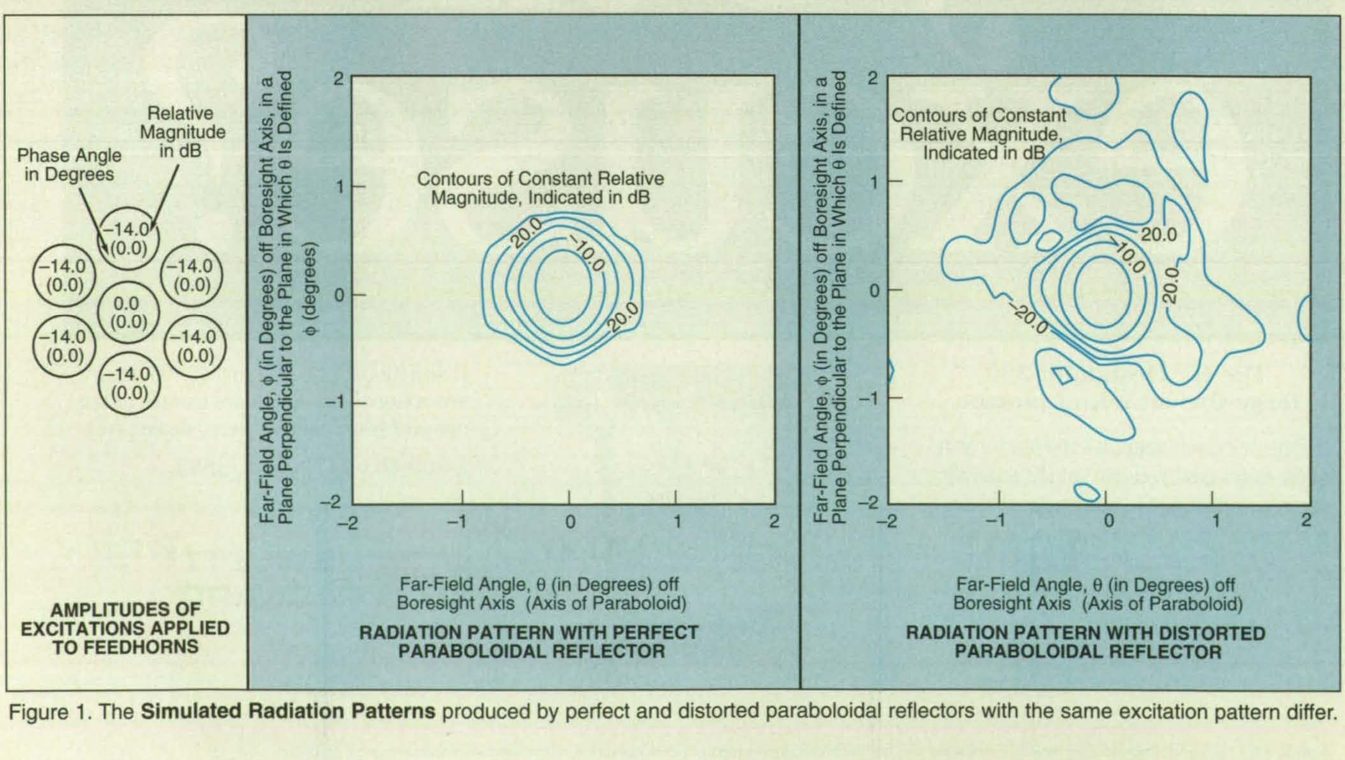

Figure 1. The **Simulated Radiation Patterns** produced by perfect and distorted paraboloidal reflectors with the same excitation pattern differ.

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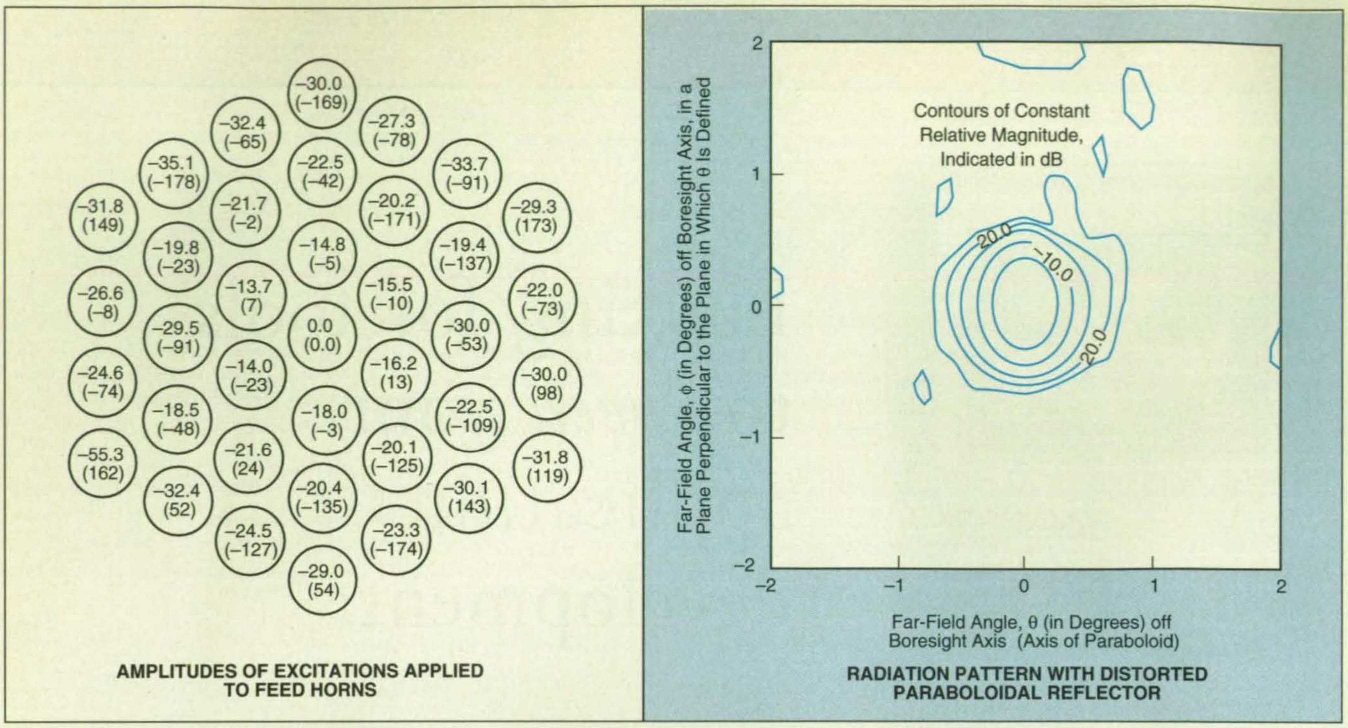


Figure 2. The **Simulated Radiation Pattern** produced by the distorted paraboloidal and 37 feedhorns excited according to the method described in the text approximates that produced by the 7 feedhorns and the perfect paraboloid of Figure 1.

by computer simulations. In one simulation, the desired field was defined as that produced by a perfect paraboloidal reflector and 7 feedhorns excited as shown in Figure 1. Also shown in Figure 1 is the simulated far-field radiation pattern produced by a distorted paraboloidal reflector with the same feedhorn excitation. Figure 2 shows the amplitudes of excitations applied to a hexagonal array of 37 feedhorns to obtain the least-squares approximation to the desired radiation pattern in the presence of the distortions, plus the resulting simulated radiation pattern.

This work was done by M. C. Bailey, C. R. Cockrell, and L. D. Staton of **Langley Research Center**. *For further information,* ***write in 139*** *on the TSP Request Card.*

LAR-14461

Display-and-Alarm Circuit for Accelerometer

The circuit is retrofit onto the accelerometer in a compact package.

Lyndon B. Johnson Space Center, Houston, Texas

Figure 1 illustrates a compact accelerometer assembly that consists of a commercial accelerometer retrofit with a display-and-alarm circuit. Heretofore, accelerometer outputs have been processed and displayed on remote equipment. The incorporation of display-and-alarm circuitry into the accelerometer package provides simple means for a technician attending a machine to monitor its vibrations. It also simplifies automatic safety shutdown by providing a local alarm or shutdown signal when the vibration exceeds a preset level.

The circuit (see Figure 2) receives the ac component of the accelerometer signal through capacitor C_1. The ac signal is rectified by diode D_1, then integrated by resistor R_1 and capacitor C_2. The integrated signal is fed to 10-level display driver Q_1 through potentiometer R_2, which is adjusted during calibration to set the full-scale acceleration at level 10 of the display. The output of the display driver is fed to bar-graph display unit Q_2. Resistor R_3 sets the brightness of light-emitting diodes in the display unit.

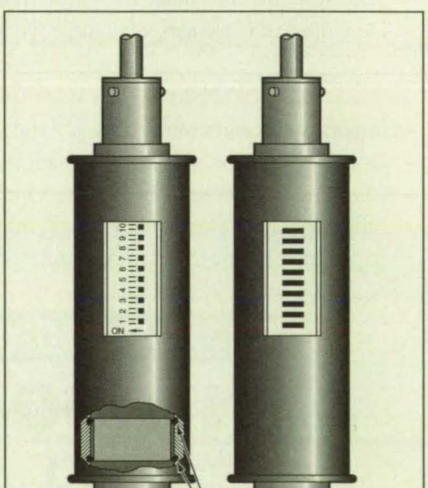
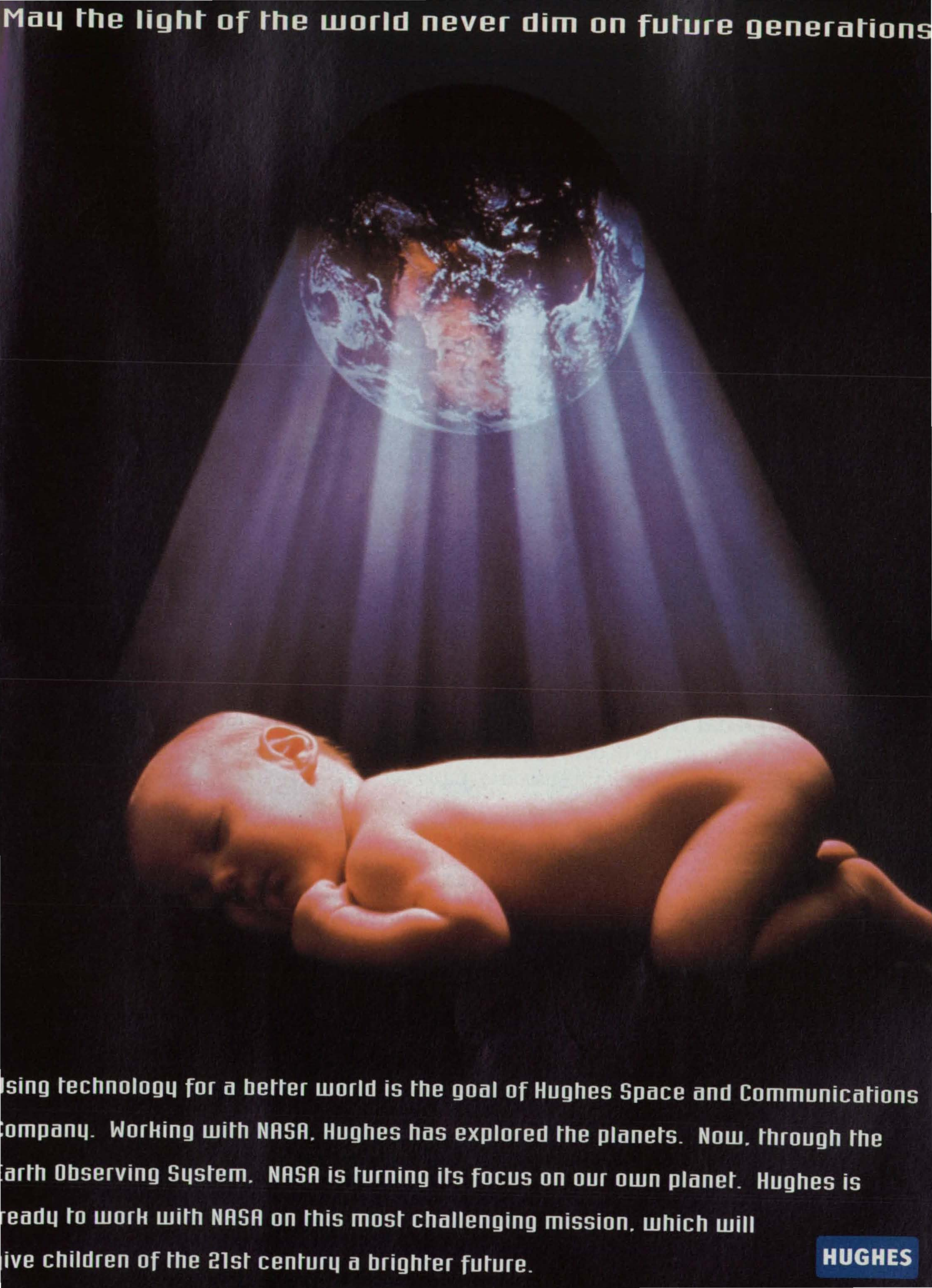


Figure 1. The **Accelerometer and Retrofit Circuitry** are assembled into one compact package.

The scale of the bar-graph display can be linear, as shown in Figure 2, or logarithmic, depending on which of two alternative display drivers is selected as Q_1. The alarm level is set by closing one of the segments of switch S_1. For example, closing segment 10 sets the alarm level at the full-scale acceleration [which, in this case, is 5 times the normal gravitational acceleration (g) at the surface of the Earth]. The level-10 display driver is thus coupled through the closed switch segment to the alarm-output terminal, which is pin 4 on the connector.

Normally, there is no connection from pin 4 though the circuit to ground. When the acceleration reaches or surpasses 5g, the display driver puts out a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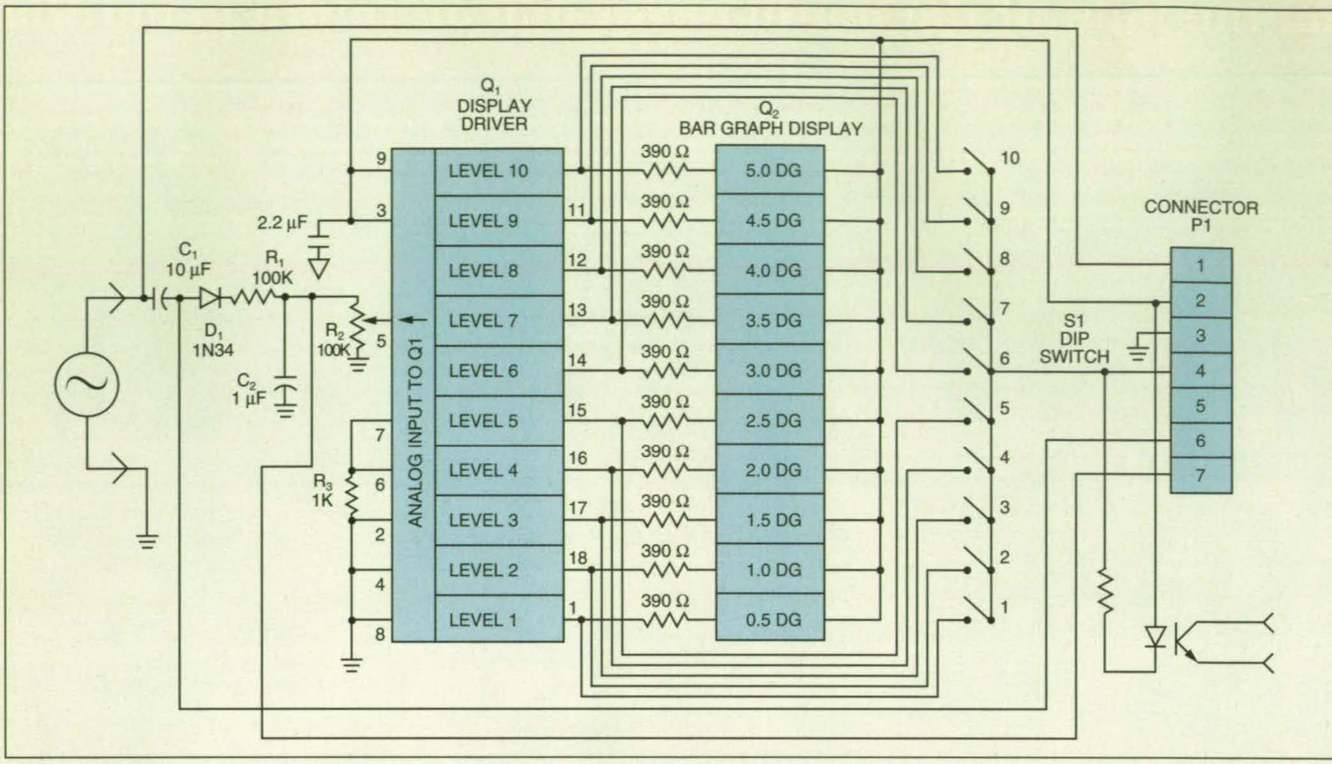


Figure 2. The **Display-and-Alarm Circuit** is made of commercially available parts.

level-10 signal, which is basically the closure of a transistor switch between its level-10 output terminal and ground. Thus, the alarm output is a switch closure, which can be used to activate alarm and/or shutdown circuitry.

This work was done by Richard J. Bozeman, Jr., of **Johnson Space Center**. *For further information,* ***write in 190*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center (see page 20). Refer to MSC-21961.

Storing Data in Circulating Electrons

Three electrons spinning up or down are represented by binary "one" or "zero."

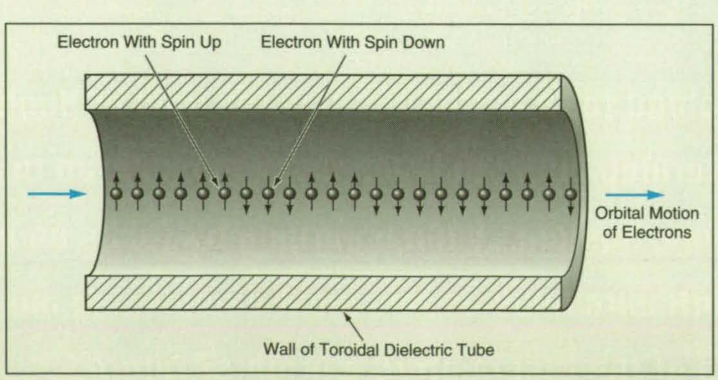
NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed memory device would contain electrons traveling in a circular orbit in a vacuum. The orientations of the electron spins (up or down) would represent binary ones or zeros, respectively (see figure). Assuming that the length of each memory element would be 100 times the classical fictitious electron radius, the device would be theoretically capable of storing 446 gigabytes of data per meter of circumference of the orbit.

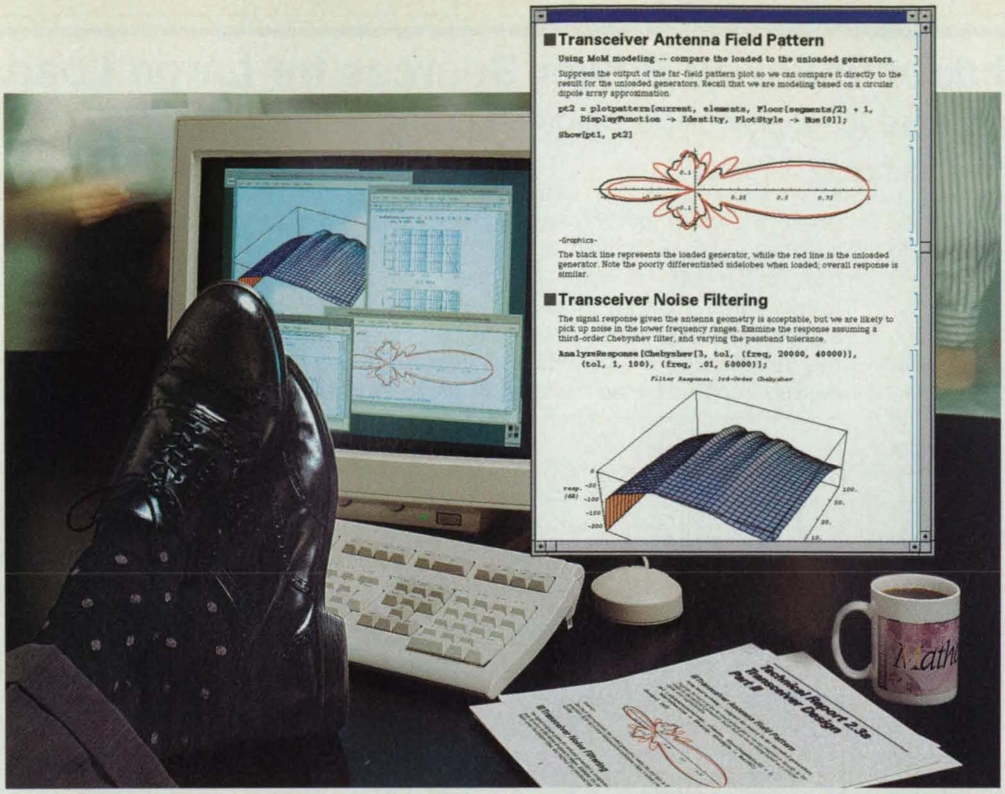
The circular orbit would lie within a toroidal dielectric tube. The interior of the tube would be evacuated. Electrons would then be injected and the tube would be sealed. An electric field oriented radially with respect to the center of the circular orbit would be imposed by electrodes on the outside of the tube. This electric field would hold the electrons in orbit, in which they would remain in serial position in single file. The electrons in orbit could be accelerated to high (even relativistic) speed by use of an alternating magnetic field like that of a betatron.

A datum would be written by momentarily applying an electric field that would change the orientation of the magnetic dipole moment of three passing electrons. A datum would be read by use of three atom probes that would sense the magnetic dipole moment of passing electrons. Some redundancy would be needed to preserve data that could be lost when electrons are scattered by virtual particles or passing particles that originated in radioactive decays. The redundancy could be provided by using three electrons to represent each data bit. In addition, a parity-checking system with feedback correction would be used.

This work was done by Ted R. Eastman of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 265*** *on the TSP Request Card. NPO-19247*



The **Orientations of Electron Spins** would signify binary ones or zeros. Each group of three electrons would represent one data bit.



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For More Information Write In No. 522

Controllable Bidirectional dc Power Sources for Large Loads

A system has been redesigned for greater efficiency, durability, and controllability.

Langley Research Center, Hampton, Virginia

Modern electronically controlled dc power sources have been proposed to supply currents to six electromagnets that are used to position an aerodynamic test model in a wind tunnel. The resistances of the electromagnet coils range from 0.5 to 2.0 Ω, and the inductances range from 0.008 to 0.40 H. The current needed in each electromagnet ranges between +90 and -30 Adc. Heretofore, the coils were energized by older power supplies, including relatively inefficient resistance-coupled thyratron-controlled rectifiers and voltage-controlled ac-to-dc motor generators, which are bulky and difficult to maintain.

The proposed source is based on a six-phase, bidirectional, controlled bridge rectifier (see Figure 1). Three-phase, 440-V power would be stepped down via either (1) a transformer that comprises a 440-V, 3-phase Y primary winding and a 63.5-V, six-phase star secondary winding and can furnish 85.3 average dc volts or (2) a transformer that comprises a 440-V, three-phase Δ primary winding and a 110-V, six-phase star secondary winding and can furnish 148 dc Volts. The transformer and voltage range of each source would be chosen according to the resistance of the coil and the desired range of load voltage in the electromagnet coil to which the source was to be connected.

Bidirectional conduction in each leg of the rectifier would be controlled by electronic switches implemented by use of two power metal oxide/semiconductor field-effect transistors (MOSFETs)

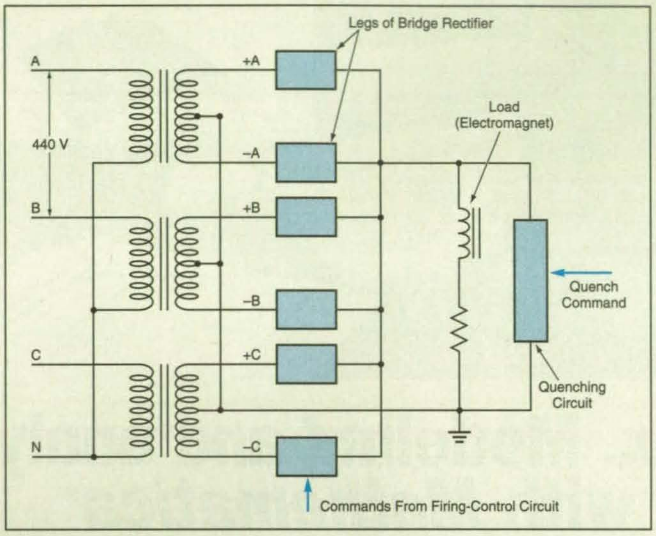


Figure 1. A **Six-Phase Bridge Rectifier** would supply the load with a large current at a voltage of commanded magnitude and polarity.

connected in parallel in opposite polarities. Each MOSFET would be protected by a series reverse-blocking diode. This bidirectional design would enable control of the load voltage via control of the switching times at each leg. Hybrid analog/digital circuitry would determine sequential switching times at successive legs of the bridge in such a way as to produce a dc load voltage proportional to a control voltage. The inductance of the load would be utilized to smooth the current. In the case of an interruption in the bridge current, a quenching circuit would shunt the load current to ground to prevent an inductive voltage impulse.

Load current would be sensed by a bidirectional Hall-effect current transducer. The output of the transducer would be processed by a current-feedback circuit (see Figure 2) that would provide high control linearity and adjustable current limiting. The current-limiting feature would impose an adjustable bound on the magnitude of the average load current, thereby also protecting against a steady or slowly varying overload. An additional overvoltage-detecting circuit would protect against a sudden open circuit in a nominally conducting leg of the bridge by activating the quenching circuit. An additional overcurrent-sensing circuit would protect against a short circuit in the load by disabling the bridge and activating the quenching circuit. Fuses and circuit breakers would protect against short circuits within the bridge.

This work was done by John S. Tripp and Taumi S. Daniels of **Langley Research Center.** *Further information may be found in NASA TM-4198 [N90-25319/TB], "A Linearly Controlled Direct-Current Power Source for High-Current Inductive Loads in a Magnetic Suspension Wind Tunnel."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, User Services Division, Linthicum Heights, Maryland, Telephone No. (301) 621-0394. Rush orders may be placed for an extra fee by calling the same number.
LAR-14664

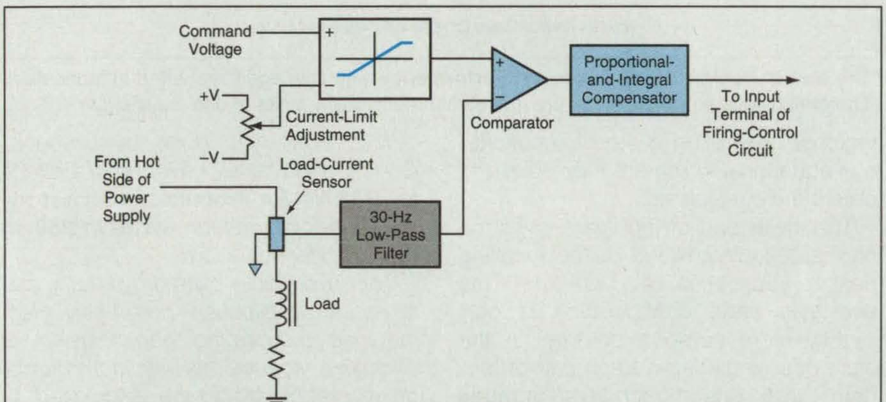


Figure 2. The **Current-Feedback Circuit** would include a current-limiting feature that would give some protection against overload.

Broadband Venetian-Blind Polarizer With Dual Vanes

Undesired reflections and deformations are reduced.

NASA's Jet Propulsion Laboratory, Pasadena, California

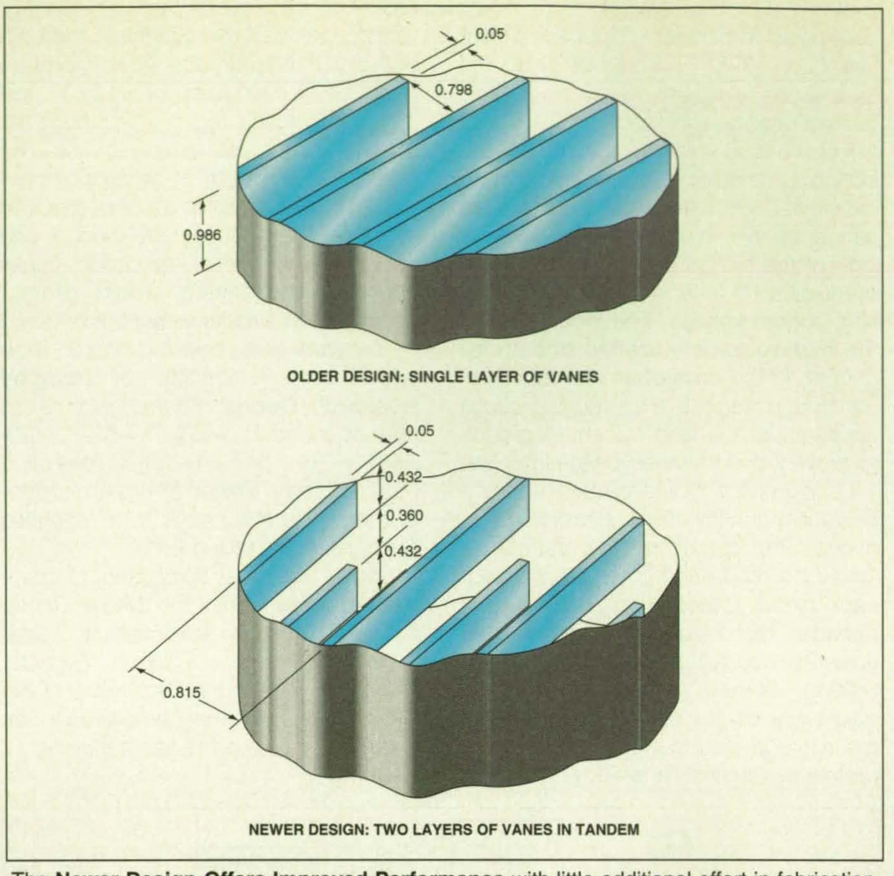
An improved venetian-blind polarizer features an optimized tandem, two-layer vane configuration that reduces undesired reflections and deformation of the radiation pattern below those of the prior single-layer vane configuration. The improved design is the product of a computerized analysis of the electromagnetic fields in the vicinity of the polarizer vanes. The analysis showed that, among other things, the reflections and deformation produced by the single-phase version arise primarily from a degenerate electromagnetic mode that is resonant at the design middle frequency and that is excited when the polarizer is illuminated slightly off axis.

A venetian-blind polarizer is mechanically and structurally simple: It consists of a number of thin, parallel metal strips (see figure) placed in the path of a propagating radio-frequency beam. Venetian-blind polarizers offer a simple way to convert polarization from linear to circular or from circular to linear. They

are particularly useful for beam-waveguide applications. When such a device is illuminated so that the electric field is at 45° to the vanes, the beam is split into two half-power beams: one in which the electric field is perpendicular to the vanes and that propagates in the transverse electric and magnetic (TEM) mode and another beam in which the electric field is parallel to the vanes and that propagates in the TE_1 parallel-plate waveguide mode.

The thickness of the polarizer is chosen so that the phase delay in propagation of the TEM mode is 90° more than that of the TE_1 mode. This condition produces circular polarization of the output. The thickness of the polarizer must also be chosen so that reflections of the TE_1 beam from the entry and exit surfaces cancel each other, thereby minimizing reflections.

Although the operation of the venetian-blind polarizer is conceptually simple, heretofore the complications introduced by edge effects in the vanes have made designing such a device more of an art than a science. To minimize the amount of "cut and try" effort needed in arriving at the design, a computer program based on matching of electromagnetic modes was written to solve the problem. The program posits an infinite number of infinitely long vanes, so that the field is periodic along an axis perpendicular to the vanes and propagates with a fixed wavelength. The field outside the polarizer is represented by a sum of one-dimensional Floquet modes with unknown coefficients. The field inside is represented by a sum of one-dimensional parallel-plate modes, also with unknown coefficients. The tangential electric and magnetic fields are matched at the boundary between the regions, generating a set of simultaneous equations, which are then solved to obtain the coefficients.



The **Newer Design Offers Improved Performance** with little additional effort in fabrication. The dimensions in the drawings are optimum dimensions in units of one wavelength.

The lower part of the figure gives the normalized dimensions of the resulting design. Fabrication of a polarizer in the two-layer vane configuration is only slightly more complicated than in the case of a single layer. Each pair of tandem vanes, one in each layer, is made from a single, wider vane simply by cutting a slot of the appropriate width out of the middle of the vane.

This work was done by Bruce L. Conroy and Daniel J. Hoppe of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 258*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL [see page 20]. Refer to NPO-19084.

Circular-Loop-Element Microwave Frequency-Selective Reflectors

Double or single planar arrays of circular loops are laminated with dielectric sheets.

NASA's Jet Propulsion Laboratory, Pasadena, California

The figure illustrates some alternative configurations of microwave frequency-selective reflectors that consist of planar arrays of circular-loop conductive elements laminated with dielectric sheets. These reflectors are designed for use in multiplexing signals at several frequencies in a microwave antenna system: specifically, they are required to be highly transmissive at frequencies of 2.3 GHz (in the S band) and 13.8 GHz (in the K_u band) and highly reflective at intermediate frequencies of 7.2 and 8.4 GHz (in the X band). A similar device was described in "Triband Circular-Loop Frequency-Selective Microwave Reflector" (NPO-18714), *NASA Tech Briefs*, Vol. 18, No. 3 (March 1994), page 41.

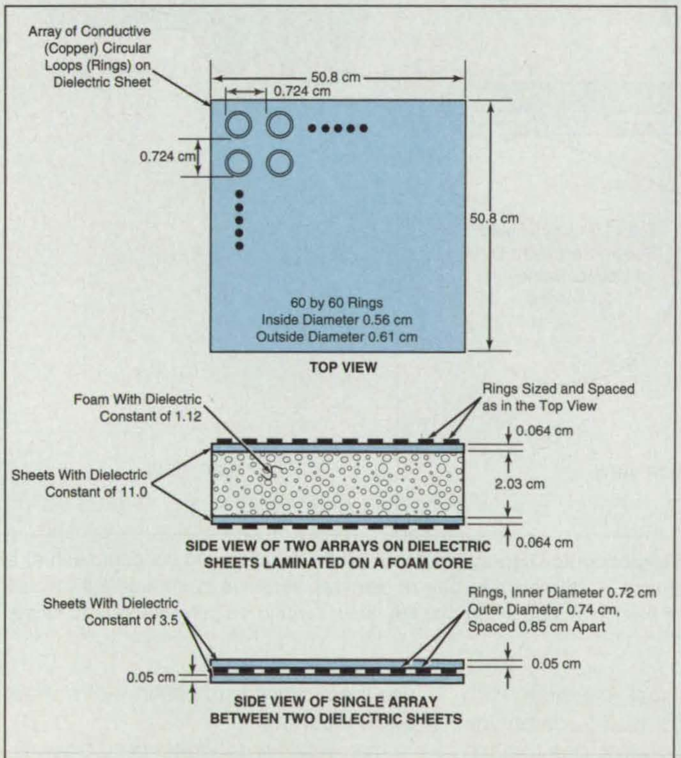
One reason for choosing circular-loop antenna elements over elements of other shapes is that they are well suited to both circularly and linearly polarized radiation. Another reason is that their transmission and reflection characteristics are relatively insensitive to the angle of incidence: these characteristics remain essentially the same throughout the range of angles of incidence (0° to 45°) that are expected to be encountered in practice.

To maximize reflection and minimize undesired nulls in the reflection pattern at the specified reflection frequencies of 7.2 and 8.4 GHz, the circular-loop elements

are designed to perform similarly to half-wavelength dipoles by making their circumferences approximately 1 electrical wavelength long at these frequencies. The distance between circular-loop elements in the array is required to be small enough (0.33 free-space wavelength) at the highest operating frequency of 13.8 GHz to prevent the array from acting like a diffraction grating and thus transmitting and reflecting radiation into grating lobes in undesired directions at that frequency. This distance would be too small to accommodate the design circumference of a circular-loop element in free space. However, because of the dielectric-loading effect (the wavelength along a conductor is smaller in the presence of an adjacent dielectric material), the loops can be made sufficiently smaller than their free-space counterparts so that they can fit within the array spacing. An adequate dielectric-loading effect can be achieved by placing the array of circular elements on a single sheet of high relative dielectric constant (11.0) and thickness of 0.064 cm. Alternatively, sheets with a lower dielectric constant (3.5) and thickness of 0.05 cm can be placed on both sides of the array.

Some transmission losses occur at 2.3 and 13.8 GHz because of partial reflections at these frequencies. The dichroic reflector containing two planar arrays of circular-loop elements is designed to minimize these losses by making the reflections cancel each other. For this purpose, the thickness of the dielectric support between the two arrays is made an integral multiple of 1/4 dielectric wavelength at 13.8 GHz and approximately 1/4 dielectric wavelength at 2.3 GHz, so that the reflection at each is opposite in phase to that from the other array. This quarter-wavelength thick layer can also be thought of as an impedance matching layer for the transmitted waves.

This work was done by John Huang and Te-Kao Wu of Caltech and Shung-Wu Lee of the University of Illinois for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 119*** *on the TSP Request Card. NPO-18940*



These **Arrays of Conductive Circular Loops** are highly reflective in the X band and highly transmissive in the S and K_u bands. The dielectric-loading effect enables the use of smaller loops with tighter spacing, thereby preventing unwanted grating lobes. The double-array configuration minimizes the remaining partial reflections in the S and K_u bands.

Helmet-Mounted Display of Clouds of Harmful Gases

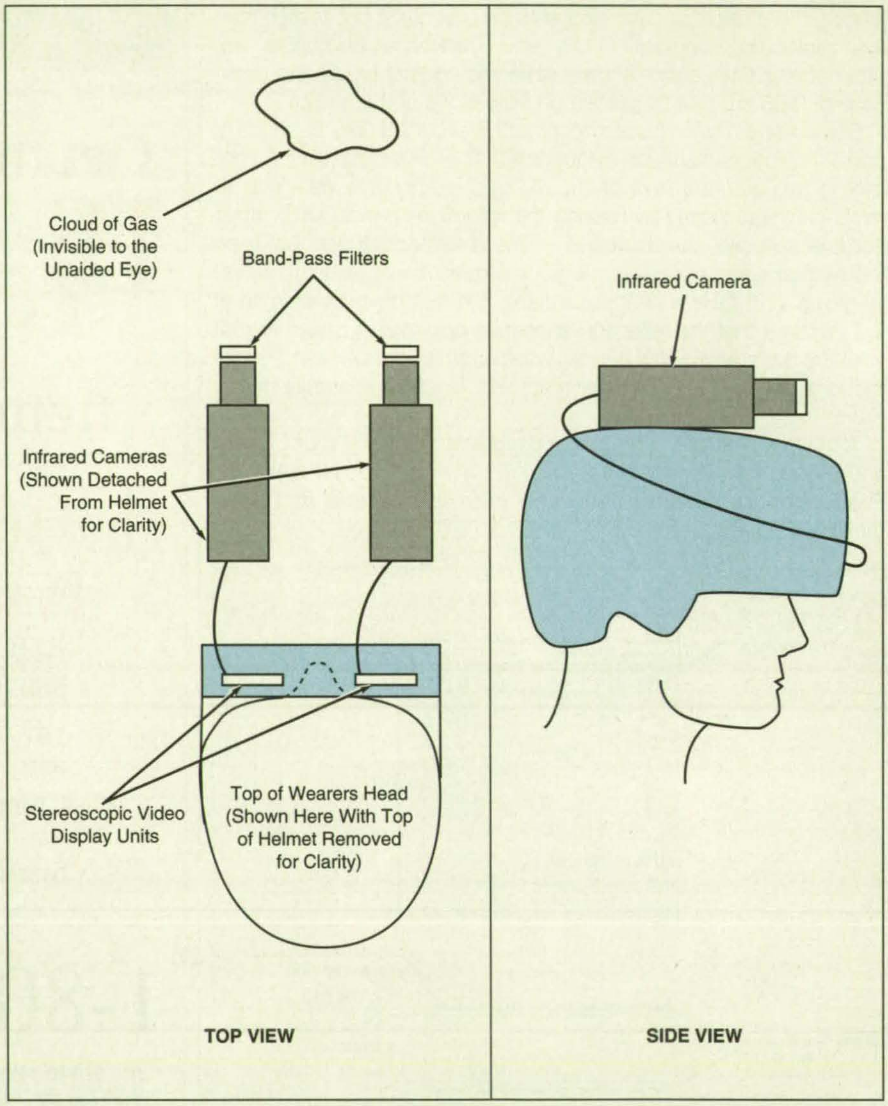
Stereoscopic images would show otherwise invisible gas clouds overlaid on background scenes.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed helmet-mounted optoelectronic instrument would provide real-time stereoscopic views of clouds of otherwise invisible toxic, explosive, and/or corrosive gas (hydrazine in the original intended application). The display would be semitransparent: the images of clouds would be superimposed on the scene that would ordinarily be visible to the wearer. Thus, the images would give indications on the sizes and concentrations of the gas clouds and their locations in relation to other objects in the scene.

Instruments like this one could serve as safety devices for astronauts, emergency response crews, fire fighters, people cleaning up chemical spills, or anyone else working near invisible hazardous gases. Similar instruments could also be used as sensors in automated emergency response systems that could activate safety equipment and emergency procedures. Both the helmet-mounted and automated-sensor versions could be used at industrial sites, chemical plants, or anywhere dangerous and invisible or difficult-to-see gases might be present.

The proposed instrument would produce the cloud images from absorption of infrared radiation in the hazardous gas in question. The instrument (see figure) would include a stereoscopic pair of infrared cameras, the lenses of which would be covered by band-pass filters that would only pass the infrared wavelengths at which the gas absorbs. Thus, a cloud of the gas would appear as a dark spot in the stereoscopic infrared images. Miniature video display units within the helmet-mounted instrument would convert the infrared images to visible light and present them stereoscopically to the wearer. The intensity of the spot (its gray level) would indicate the concentration of the gas in the cloud. Either sunlight or infrared emitters could provide the infrared illumination to form the cloud images. In a case in which gases other than the one of interest also absorb at the same wavelength(s), then additional filters or additional cameras with other filters could be used to determine how much absorption was due to each of the gases.



A **Helmet-Mounted Stereoscopic Display** would reveal the location and concentration of a hazardous gas in real time. A stereoscopic pair of cameras sensitive to infrared light would produce the images of the hazardous cloud that the viewer would visually integrate to locate the cloud.

In addition to the helmet-mounted and automated-sensor versions, there could be a hand-held version. In some industrial applications, it could be desirable to mount these instruments and use them similarly to parking-lot surveillance cameras.

This work was done by Daniel B. Diner, Jack B. Barengoltz, and Wayne R. Schober of Caltech for **NASA's Jet Pro-pulsion Laboratory.** *For further information,* ***write in 3*** *on the TSP Request Card.*
NPO-18759

Two Unipolar Terminal-Attractor-Based Associative Memories

Unipolar models make optical implementation more practical.

NASA's Jet Propulsion Laboratory, Pasadena, California

Two unipolar mathematical models of an electronic neural network that functions as a terminal-attractor-based associative memory (TABAM) have been developed. The models comprise sets of equations that describe the interactions between time-varying inputs and outputs of the neural-network memory, which is regarded as a dynamical system. In each model, the dynamical state of the system is represented by a state vector, and the model is called "unipolar" because each component of the state vector is expressed as a sum of positive terms. In comparison with other mathematical models of a TABAM, these models offer an advantage in that they simplify the design and operation of an optoelectronic processor to implement a TABAM that performs associative recall of images. Unipolarity is an important element of the simplification in that it eliminates the need for subtraction, which is difficult to implement in optical processing.

The TABAM concept was described in "Optoelectronic Terminal-Attractor-Based Associative Memory" (NPO-18790), Laser Tech Briefs, Vol. 2, No. 2, (Spring, 1994), page 69. An experimental optoelectronic apparatus that performed associative recall of binary images (with black and white pixels) was described in "Optoelectronic Inner-Product Neural Associative Memory" (NPO-18491), NASA Tech Briefs, Vol. 17, No. 3 (March, 1993), page 45. To recapitulate: Unlike a neural network based on the older Hopfield model, a neural network based on terminal attractors and an adaptive threshold can be made to function without spurious states and to converge, in iterative cycles of stimulus/feedback/response, to an exact remembered state. In the present case, this means that the output image can be made to converge to one of a number of stored binary images after the system has been stimulated by initial input in the form of an incomplete version of the stored image. The elimination of spurious states increases the storage capacity (the number of true states to which the system can converge) by an order of magnitude.

One of the present mathematical models is called the "unipolar inner-product TABAM" (UIT); the other is called the "crosstalk-reduced inner-product TABAM" (CRIT). The UIT is made unipolar by incorporating an adaptive threshold function, q(t). A logistic function $g[x_i(t)]$ (where x_i denotes the ith component of the state vector at time t) is used in conjunction with q(t) (see Figure 1).

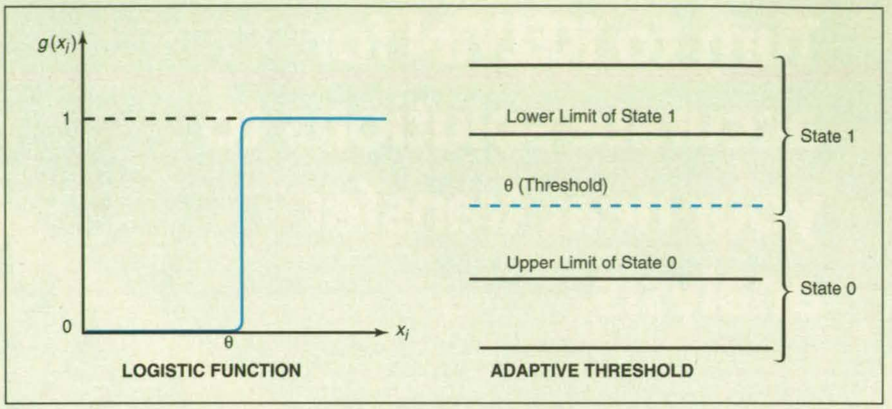


Figure 1. The **Adaptive Threshold**, $\theta(t)$, is used in conjunction with the logistic function $g[x_i(t)]$ to perform a nonlinear transformation such that the output becomes a quasi-binary state. To maximize immunity to noise and thereby promote convergence, the threshold is set between the lower limit of output state 1 and the upper limit of output state 0.

The UIT is applicable when the stored state vectors are all orthogonal, in which case the system is said to be free of crosstalk. The CRIT applies to the more practical case in which all the stored states are not orthogonal and crosstalk often occurs between similar stored state vectors. The CRIT involves a modified version of q(t), along with modified version of the equation for $x_i(t)$ in which the crosstalk between nonorthogonal stored vectors is weighted and reduced. The CRIT provides a mechanism that (1) puts the input state vector into the basin of attraction of the correct stored vector in the state space, then (2) uses the terminal attractor to accelerate convergence. The CRIT does not require any training time, and therefore can be readily implemented by optoelectronic means.

The UIT and CRIT models performed successfully, demonstrating perfect convergence when tested by computer simulation and in experiments using stored binary images of 2 ¥ 2 pixels. Figure 2 illustrates the experimental apparatus. The computer sends the input image to spatial light modulator 1 (SLM1), which is a liquid-crystal television light valve. SLM1 is illuminated by a collimated beam from an argon laser. The image on SLM1 is Fourier-transformed by lens L1 and filtered by two pinholes on plane F to pass the +1 and –1 diffraction orders of grid patterns of SLM1. The passed +1 and –1 orders are inverse-Fourier-transformed by L2, and exclusive-OR (XOR) operations are

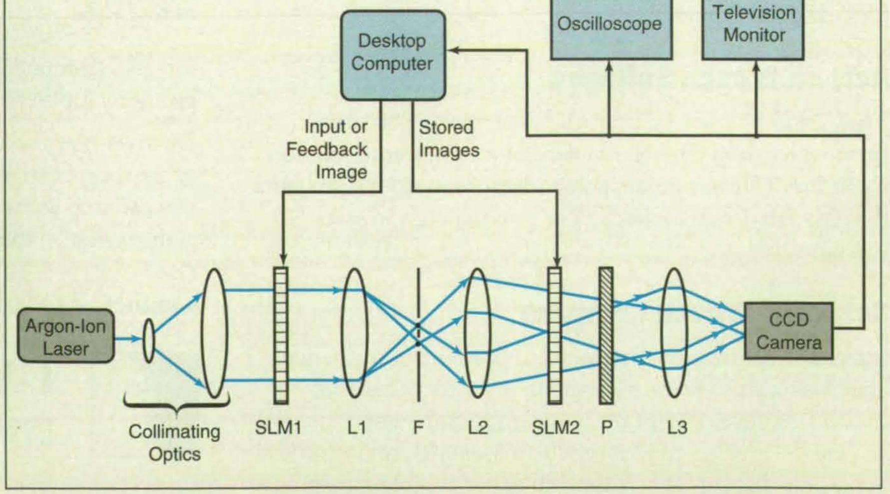
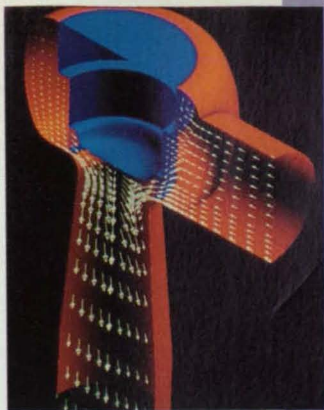


Figure 2. This **Optoelectronic Apparatus** performs associative recall of a binary image.



Velocity vectors reveal flow patterns through the center section of this steam turbine inlet throttle valve.

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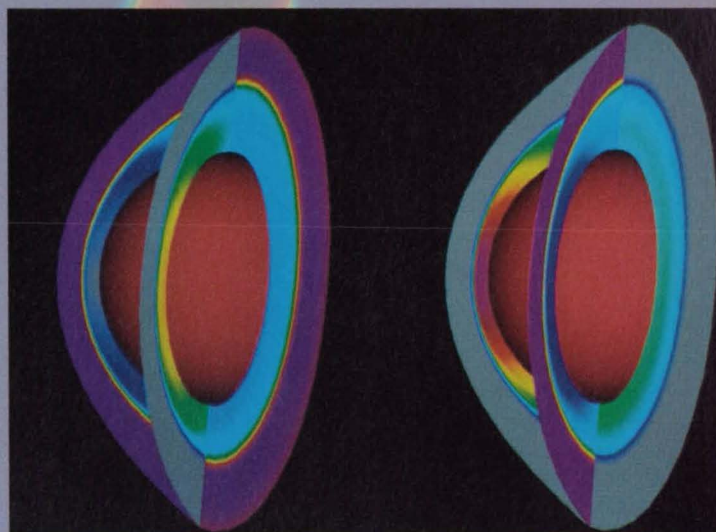

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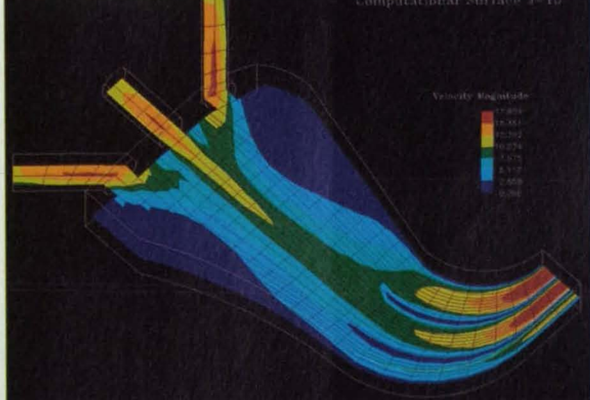

Velocity magnitude on center plane through a multi-port transition duct.

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performed with the two images stored in SLM2 (which is also a liquid-crystal television light valve). The XOR results are detected by a charge-coupled-device (CCD) camera and sent to the computer to compute the state vector of the next iteration. This vector is fed back as input to SLM1 to obtain the next state of the dynamical system. This process is iterated until convergence is reached. The converged state is displayed on SLM1 or on a television monitor.

This work was done by Hua-Kuang Liu of Caltech and Chwan-Hwa Wu of Auburn University for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 125*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL [see page 20]. Refer to NPO-19123.

Direct Adaptive Impedance Control of Redundant Manipulators

Detailed dynamical models and inverse kinematic transformations are not needed.

NASA's Jet Propulsion Laboratory, Pasadena, California

A method of controlling the mechanical impedance of the end effector of a robotic manipulator is related to the method described in "Adaptive Impedance Control of Redundant Manipulators" (NPO-18606), NASA Tech Briefs, Vol. 18, No. 5, (May, 1994), page 28. Like the previously described method, the present method is computationally efficient in that it does not require detailed knowledge and computation of the dynamics and the inverse kinematic transformation of the manipulator. The present method provides for control that is globally stable in the presence of bounded disturbances. The present method is applicable to both nonredundant and redundant manipulators performing tasks that involve (1) impacts between the manipulator and objects in its environment, and (2) controlled contact between the end effector and an object, such as deburring.

In an impedance-control approach, the control objective is to maintain a desired dynamic relationship between the position of the end effector of the manipulator and the force of contact between the end effector and any object(s) in its environment. This approach entails a unified theoretical framework for control of both constrained and unconstrained motions, without the need to switch between separate position-control and force-control modes as is necessary in hybrid position-control/force-control systems.

In the present method, impedance control of a manipulator is effected by a control system that contains three subsystems (see figure), which can be implemented in hardware and/or software. The first subsystem is an impedance filter, which characterizes the dynamic relationship between the end effector position error and the force of contact. [The end effector position error is the difference between the actual position ($\mathbf{x}$) of the end effector and a reference position ($\mathbf{x}_r$) that is the commanded trajectory.] The inputs to the impedance filter are $\mathbf{x}_r$ and a vector of force- and torque-sensor outputs ($\mathbf{P}_m$) that represent the contact force. The output of the impedance filter is a modified position command, $\mathbf{x}_d$, which is the desired impedance trajectory.

The second control subsystem implements an adaptive strategy for generating a control input, in the form of force commands ($\mathbf{F}$) in the Cartesian space of the end effector, that makes $\mathbf{x}$ track $\mathbf{x}_d$ closely. The adaptive-control strategy involves no prior knowledge of the dynamics. Instead, matrices of parameters that characterize the dynamics are updated by repeated observation of the performance of the manipulator. The adaptation laws are derived by use of a Lyapunov-stability-based design method.

The third control subsystem is an algorithm for mapping from $\mathbf{F}$ to a physically realizable vector of control torques $\mathbf{T}$. For a kinematically redundant manipulator, the $\mathbf{F} \rightarrow \mathbf{T}$ mapping, considered by itself, is undetermined in the sense that an infinite number of joint-torque vectors $\mathbf{T}$ can correspond to the same control input $\mathbf{F}$. By proper selection of a particular $\mathbf{T}$ from among them, one can exploit this redundancy by resolving it in a way that improves some quantitative measure of performance of the manipulator task. In particular, the third control subsystem can be designed to resolve the redundancy in such a way as to minimize kinetic energy, reduce impact forces, enhance compatibility among tasks, avoid obstacles in the workspace, and maximize mechanical advantage.

A computer simulation on a mathematical model of a planar four-degree-of-freedom redundant manipulator demonstrated the effectiveness of this method for control of impedance and utilization of redundancy. The results of the simulation showed that the controller is globally stable and capable of achieving arbitrarily small tracking errors. A computer simulation was also performed on a mathematical model of a seven-degree-of-freedom industrial robot. The results of this simulation showed that this method provides accurate control during constrained motion, unconstrained motion, and transitions between them.

This work was done by Homayoun Seraji of Caltech and Richard D. Colbaugh and Kristin L. Glass of New Mexico State University for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 116*** *on the TSP Request Card. NPO-18849*

Direct Adaptive Impedance Control can be implemented by a combination of three control subsystems that provide accurate tracking of a desired impedance trajectory.

Self-Checking Pairs of Microprocessors

Outputs of two microprocessors are compared repeatedly to detect faults.

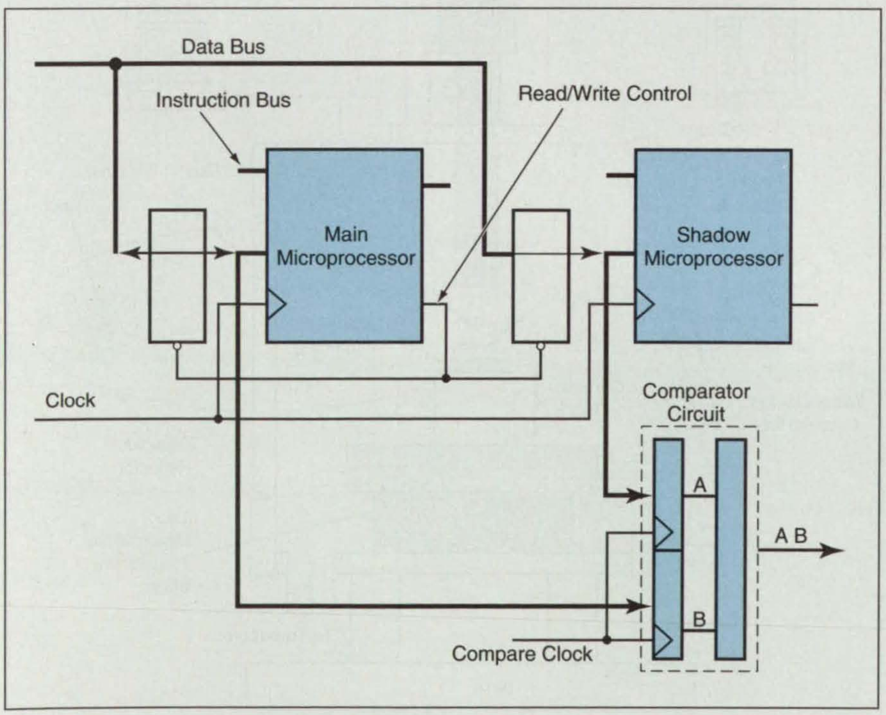
Goddard Space Flight Center, Greenbelt, Maryland

A method of imparting fault tolerance to a computer system provides for immediate detection of faults at the microprocessor level. The method involves the use of two microprocessors that are paired in such a way as to enable detection of faults in one of them. The method can be implemented with minimal redundancy (the only circuitry that has to be duplicated is the microprocessor, the functioning of which is to be verified) and the only additional circuitry needed is a comparator circuit (see figure).

Of the output pins of the two microprocessors, those of the main microprocessor are connected to the system that the microprocessor serves. The output pins of the redundant microprocessor (called the "shadow" microprocessor) are connected to the comparator circuit only. In addition to pins for connection to data buses, each microprocessor includes clock, interruption, and control pins, and pins for connection to an instruction bus and a general-purpose bus. A typical 32-bit microprocessor has a total of 256 pins (which include power and ground pins) that are available for comparison, although a subset may be chosen which provides a high degree of detection.

The two microprocessors are operated in synchronism, both connected to the same data bus and receiving the same input signals. At a predetermined time in each clock cycle when the output signals on all affected pins of both microprocessors are supposed to be identical and stable, the signals on corresponding paired pins are compared. When a discrepancy is found, and depending on the nature of the discrepancy, the comparator puts out an alarm signal, which can be used to initiate an appropriate corrective action. For example, if the fault is a temporary one like a single-event upset (alteration of a logic state by impact of an energetic ionizing particle), the microprocessors could be commanded to re-execute a queue of operations.

This work was done by Brian S. Smith of **Goddard Space Flight Center**. *For further information,* ***write in 4*** *on the TSP Request Card. GSC-13626*



The **Shadow Microprocessor** provides nominal duplicate outputs to verify the functioning of the main microprocessor. When the output signal on any pin of one microprocessor differs from that on the corresponding pin of the other microprocessor, the comparator puts out an alarm signal.

High-Temperature/Vacuum Fiber-Pushout Apparatus

Fiber-pushout tests can be performed at temperatures up to 1,100 °C.

Lewis Research Center, Cleveland, Ohio

Fiber-pushout testing has become an important tool for evaluating the strength of the fiber/matrix interface in fiber-reinforced composite materials. This interfacial strength strongly affects the overall mechanical strength and toughness of the composite. A previous Brief, "New Testing Tool for Composite Interfaces" (LEW-15297), NASA Tech Briefs, Vol. 18 No. 1 (January 1994), page 49, described an apparatus designed to perform fiber-pushout testing at room temperature. However, to aid development of high temperature composites, such as the composite materials being developed at NASA Lewis Research Center for future generations of jet engines, fiber pushout testing needs to be performed over the temperature range of the intended application. The apparatus described here performs fiber-pushout testing at elevated temperatures up to 1,100 °C in vacuum.

Figure 1 shows a schematic diagram of the apparatus designed for elevated temperature testing. The idea behind the test is to measure the force that is required for a pushrod (typically 100 µm diameter) to displace an individual fiber (typically 140 µm diameter) in a thin slice of composite material. A channel in the tantalum support block accommodates the bottom end of the displaced fiber without resistance. The specimen and the punch used as the pushrod reside inside a cubical vacuum chamber, which is evacuated by a turbopump. The downward motion of the punch is produced using a linear motion feedthrough driven by a computer-controlled stepper motor. The force applied by the punch is measured by the load cell attached to the shaft of the linear motion feedthrough.

Specimen heating is achieved by focusing the heating radiation from a quartz halogen lamp outside the test chamber onto the specimen and indenter inside the test chamber. The specimen temperature can reach 1,100 °C in approximately 10 minutes. Alignment of an individual fiber with respect to the punch is performed by positioning the sample with a remotely controlled translation stage so that the fiber to be tested is centered directly underneath the indenter, as observed on the TV monitor.

A microscope and video camera positioned outside the test chamber provide real-time video monitoring of the test. A video tape is made of the image from the microscope overlaid with a computer-generated plot of the load vs. displacement data. This video tape can be replayed, and the operator can confirm whether an observed feature in the data

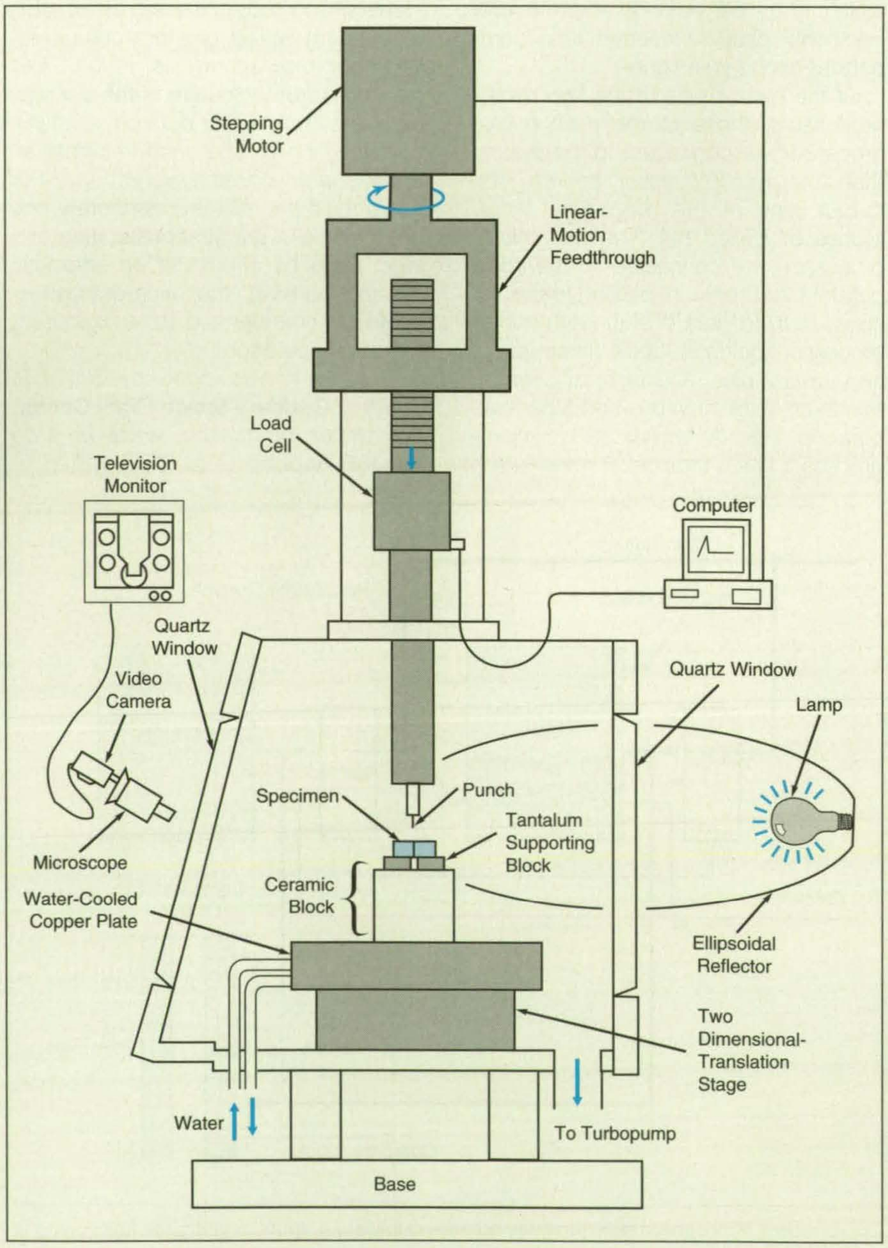


Figure 1. **This Apparatus Performs Fiber-Pushout Tests** using radiant heating in a vacuum. The vacuum maintained by the turbopump prevents significant specimen oxidation during the test.

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corresponds to fiber movement, or, for example, a matrix crack. In addition, the data is stored on a floppy disk for later display (Figure 2) and analysis.

The described apparatus has been successfully applied to metal and ceramic matrix composites being developed for jet engines. It should be equally applicable to many industrial applications, such as automotive components and energy-conversion devices.

This work was done by Jeffrey I. Eldridge and Ben T. Ebihara of **Lewis Research Center** *and Duane Dixon of the Army Research Laboratory. For further information,* ***write in 173*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center [see page 20]. Refer to LEW-15770.

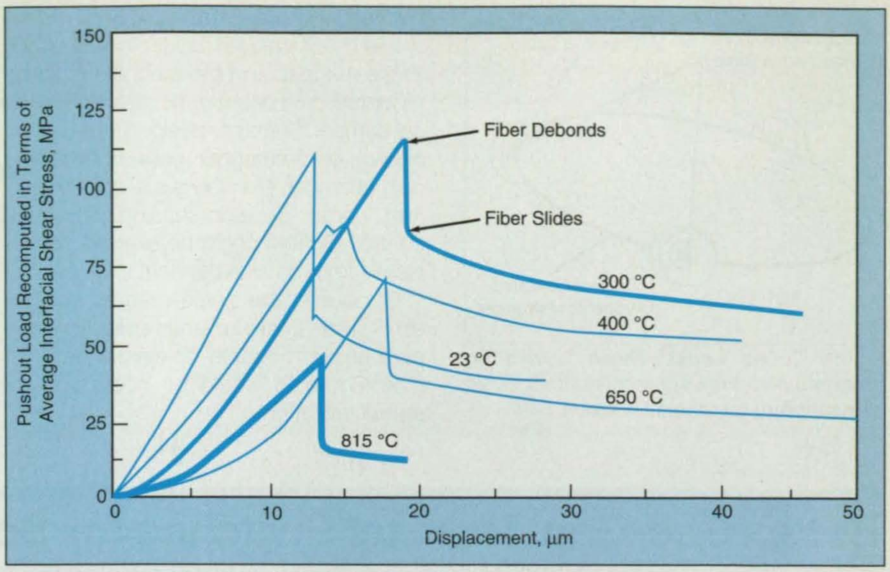


Figure 2. **These Results of Fiber-Pushout Tests** at high temperatures were attained in a specimen of a titanium/aluminum/niobium intermetallic matrix reinforced with silicon carbide fibers.

Magnetic Levitators With Superconductive Components

Vibrations could be damped electrically or mechanically

NASA's Jet Propulsion Laboratory, Pasadena, California

Magnetic noncontact levitators that include superconductive components would provide vibration-damping suspension for cryogenic instruments, according to a proposal. Because the superconductive components would be attached to the levitated cryogenic instruments, no additional coolant liquid or refrigeration power would be needed to keep these components cold. Furthermore, because the vibration-damping components of the levitators would be located outside the cold chambers, in ambient environment, it would also not be necessary to waste coolant liquid or refrigeration power on the dissipation of vibrational energy.

Many conceptual levitator designs are possible. Figure 1 shows two of them. In the design shown at the left, a superconductive coil or solid sheet of superconductive material would be attached to the cryogenic instrument, while a permanent magnet would be mounted in a fixed position outside the cold chamber. A pickup coil would be wound around the magnet and connected to a resistor.

The instrument would be levitated, via the Meissner effect (expulsion of the magnetic field from the interior of the superconductor) and by the consequent repulsion between the superconductor and the magnet. Vibrations of the levitated instrument would cause changes in the magnetic flux, which would induce voltages in the coil. These voltages and the associated currents in the resistor would heat the resistor, thereby dissipating the vibrational energy.

The design shown at the right would be similar, except that there would be no pickup coil, the magnetic repulsion

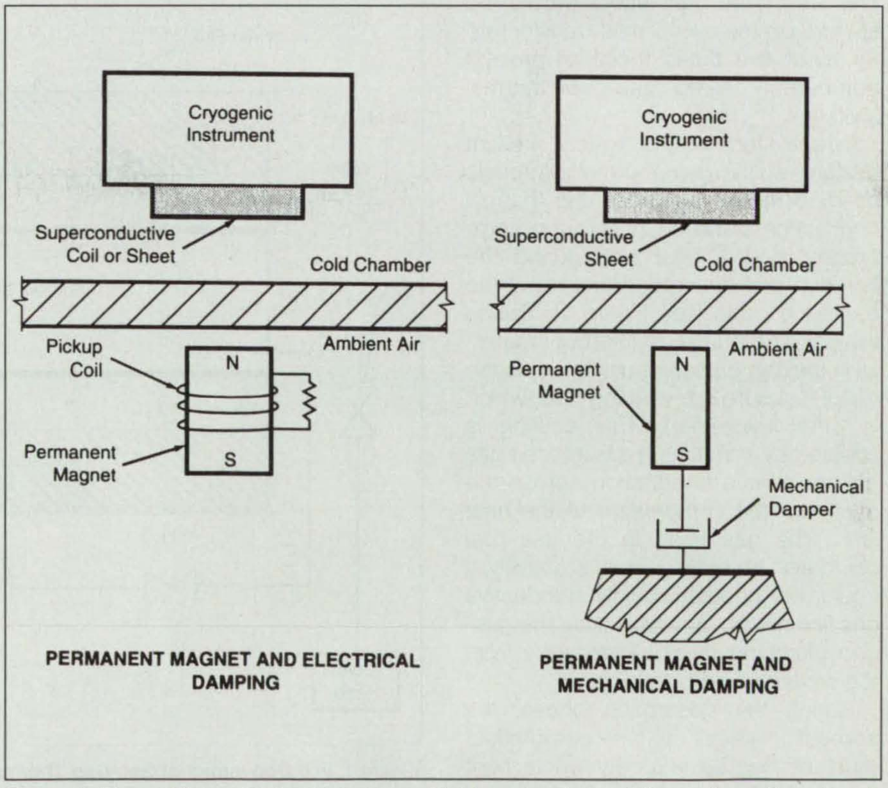


Figure 1. These **Magnetic Levitators** would take advantage of the refrigeration already available in the levitated cryogenic instrument, without adding to the refrigeration load.

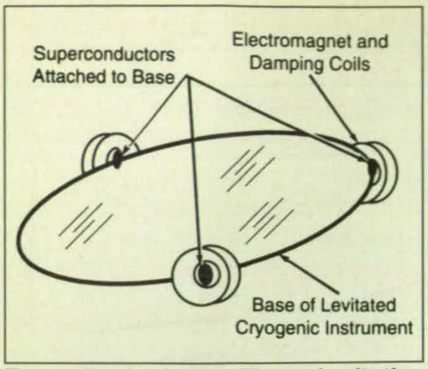


Figure 2. **At Least Three Levitating Magnets** and three superconductors would be necessary for stable levitation.

between the superconductor and magnet would be allowed to transfer the vibrations to the magnet, and the magnet would be mounted on a dashpot or other mechanical damper. Still other designs (not shown) involve electromagnet coils outside the cold chamber, possibly supplied with current under position-sensing feedback control. Control could be exerted conveniently from outside the cold chamber.

Of course, the single-magnet devices of Figure 1 are oversimplified. Three permanent magnets or electromagnets (see Figure 2) would be necessary for stable levitation.

This work was done by Benjamin P. Dolgin of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 37*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office-JPL [see page 20]. Refer to NPO-18458.

Better Gas-Gap Thermal Switches for Sorption Compressors

Convection and turbulence in the gas gaps would increase the transfer of heat.

NASA's Jet Propulsion Laboratory, Pasadena, California

Gas-gap thermal switches associated with the sorption compressors of some heat pumps and cryogenic systems would be designed for higher performance, according to a proposal, by introducing controlled turbulent flows into the gas gaps. In present gas-gap thermal switches, flow does not play a significant role, and heat is transferred through the gases in the gaps mainly by conduction. In the turbulent flows of the proposed gas-gap thermal switches, convection and mixing would contribute (in addition to conduction). The estimated net effect would be to increase the overall heat transfer rate to about five times those of present comparably sized gas-gap thermal switches.

In a system with a typical present design, a gas-gap thermal switch is used to make and break the thermal connection between a sorption compressor and a heat sink during the sorption and desorption phases of the operating cycle (see Figure 1): During the sorption phase, the sorbent material in the compressor must be cooled to make it absorb the working fluid (which is often hydrogen). This cooling is effected by admitting a gas into the gas gap to enable conduction across the gap from the compressor to the heat sink. The gas used in the gas gap could also be hydrogen. Alternatively, it could be another, highly conductive gas like helium, in which case the gas-gap plumbing must be separate from the working-fluid plumbing.

During the desorption phase, the sorbent material in the compressor must be heated (e.g., by waste heat from another source or from an internal electrical heater) to make it desorb the working fluid. To promote rapid and efficient heating, the gas gap must be evacuated to minimize the transfer of heat across the gap from the sorbent compressor to the heat sink. There is still some residual transfer of heat through radiation and conduction along peripheral paths, but typically the overall rate of transfer in this "off" state is only about 1/100 that in the "on" state.

In a typical system of the proposed type (see Figure 2), the hydrogen gas or other working fluid would also serve as the heat transfer medium in the gas gap: During the sorption phase, valves 1 and 3 would be opened and valves 2 and 4 closed, so that the working fluid evaporating from the cold head (which would absorb heat from the chamber to be cooled) would pass through the gas gap on the way to the sorbent bed. Helical fins that protruded part way across the gas gap from both the inner (sorbent-compressor) and outer (heat-sink) sides would promote rapid, turbulent flow in the gap, as needed to

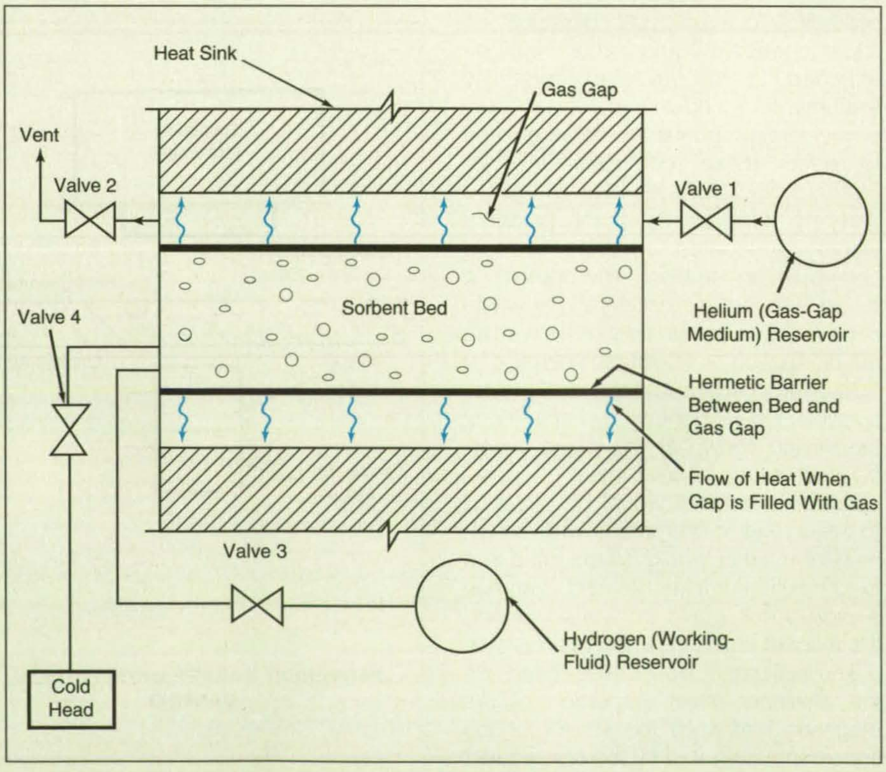
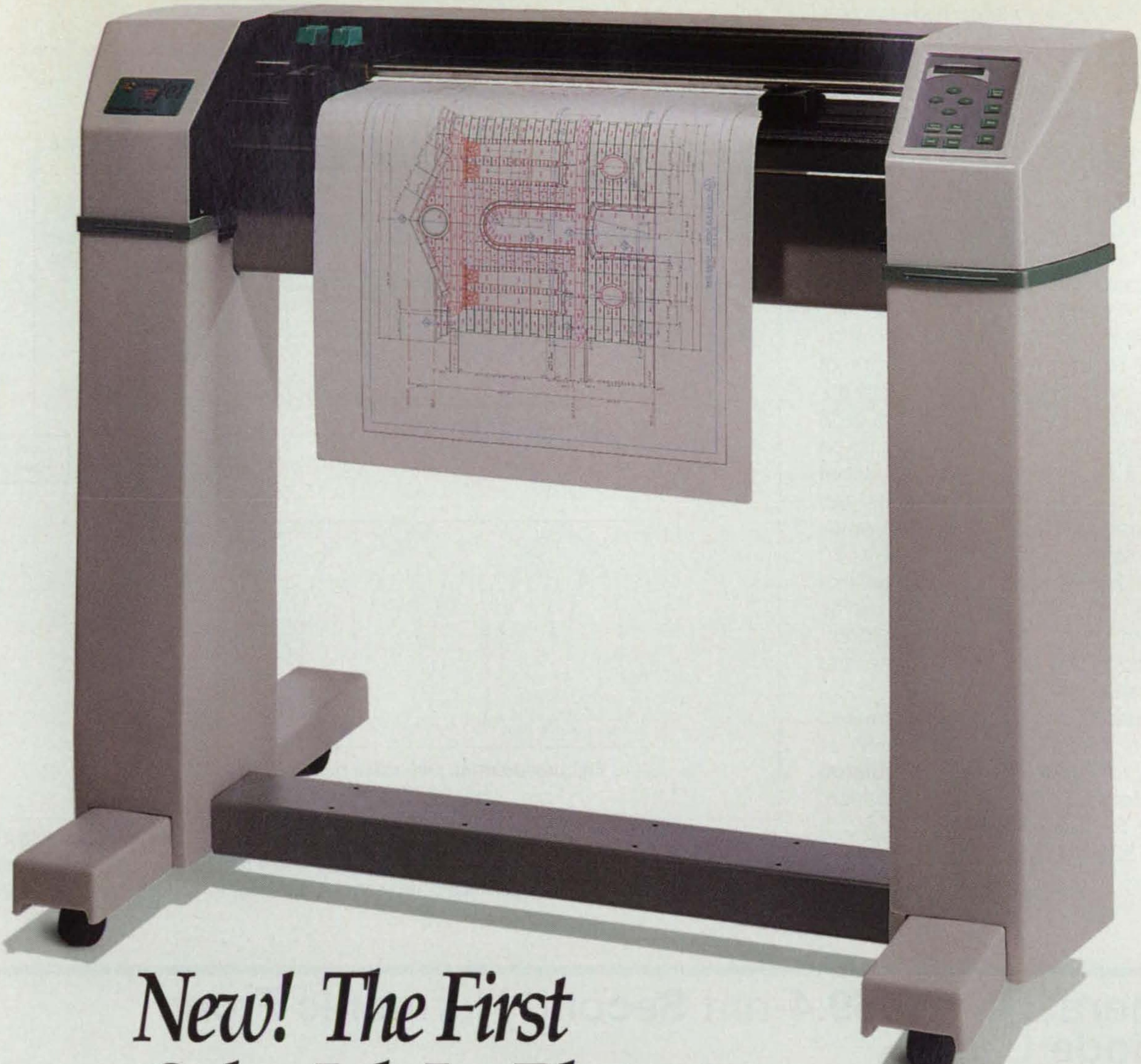


Figure 1. In a **Conventional Gas-Gap Thermal Switch**, heat is transferred primarily by conduction through the gas in the gap. The gas in the gap can be different from the working fluid.



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achieve the required large heat-transfer rate.

At the end of the sorption phase, valves 1 and 3 would be closed and valve 2 opened to evacuate the gas gap to a suitable vacuum source, without having to vent the entire supply of working fluid from the system. Valve 4 would be opened and the sorbent bed would then be heated, filling the reservoir with pressurized working fluid to be used in the next cooling cycle.

A typical gas-gap thermal switch is required to transfer heat at a rate of about 1 kW in the "on" state. With the proposed design, the temperature drop across the estimated gas gap would be about 25 K, as compared with about 120 K in a 1 kW conventional gas-gap heat switch. Assuming hydrogen working fluid at an upstream pressure of 30 psi (207 kPa) and a gap thickness of 0.060 in. (1.5 mm) with helical fins as described above, the estimated pressure drop in the flow through the gap would be about 3 psi (21 kPa).

This work was done by Pradeep Bhandari and Jose Rodriguez of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 5*** *on the TSP Request Card.*
NPO-18826

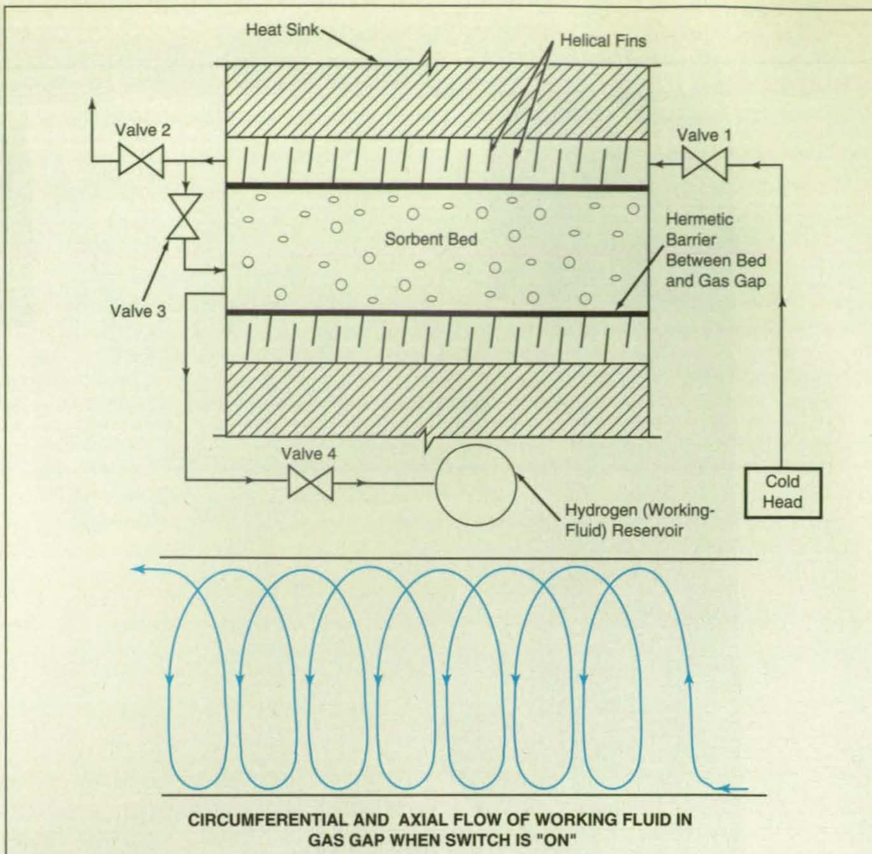


Figure 2. A **Proposed Gas-Gap Thermal Switch** would utilize convection in a turbulent flow to transfer heat at a greater rate. This particular design would take advantage of the flow of working fluid, that is, the working fluid would also serve as the heat transfer medium in the gas gap.

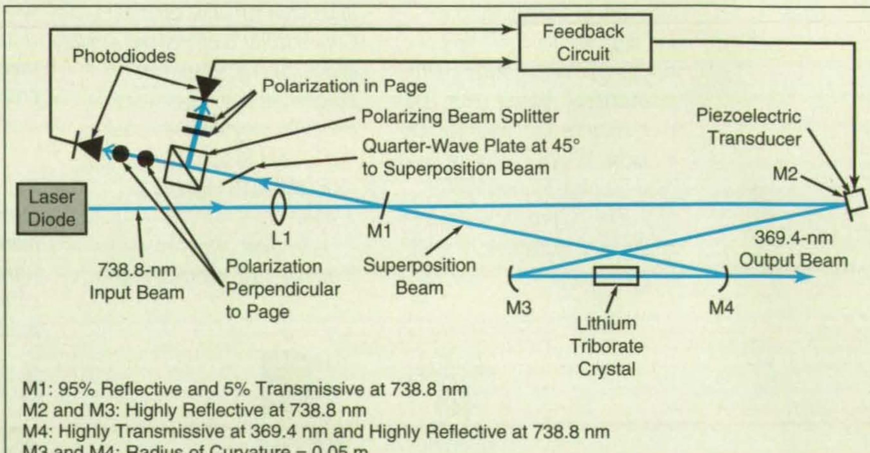
Generation of 369.4-nm Second Harmonic From a Diode Laser

The experimental laser system features a polarization feedback scheme that maintains frequency lock.

NASA's Jet Propulsion Laboratory, Pasadena, California

An experimental laser system generates light at a wavelength of 369.4 nm by second-harmonic generation from a 738.8-nm laser diode. The system is a prototype of a source of 369.4-nm radiation that will be used to optically pump the 2S1/2 ´ 2P1/2 transition in 171Yb+ ions in a lightweight, low-power trapped-ion frequency-standard apparatus. In a preliminary experiment with a commercial AlGaAs laser diode supplying 7.3 mW of input optical power at 738.8 nm, the system generated 2.0 mW of output power at 369.4 nm.

The experimental laser system has a folded-ring configuration (see figure). The frequency-doubling medium is a crystal of lithium triborate, which was chosen because of its transparency at 369.4 nm and its comparatively large acceptance angle. The crystal is angle-cut for doubling the frequency of 738.8-nm radiation and coated to minimize reflection at 738.8 nm. The crystal is mounted in the folded-ring resonant cavity defined by flat mirrors M1 and M2 and concave mirrors M3 and M4. The concave mirrors have the short focal lengths needed to focus



This **Folded-Ring Laser System** generates the second harmonic of 738.8-nm light from a diode laser.

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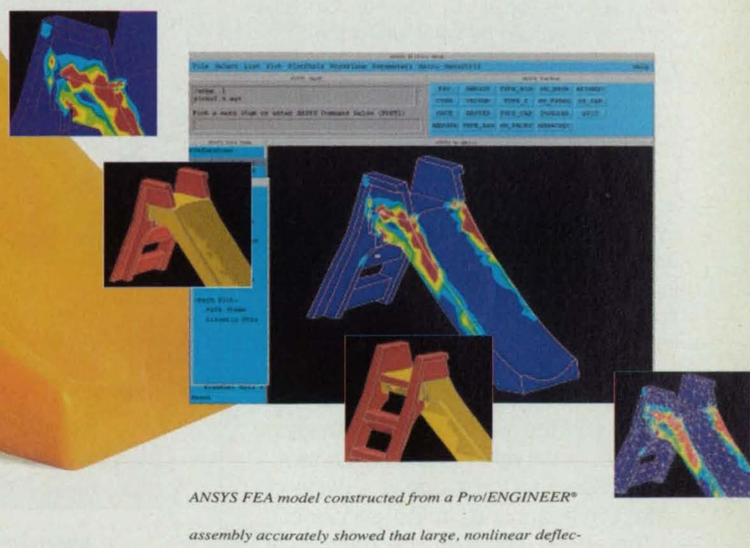


ANSYS FEA model constructed from a Pro/ENGINEER® assembly accurately showed that large, nonlinear deflections tripled the maximum stresses in the slide handrail.

Photograph and FEA model provided courtesy of Today's Kids, Dallas and DRD Corporation, Tulsa.

For More Information Write In No. 507

the 738.8-nm beam in the crystal. Lens L1 (focal length 160 mm) enables accurate matching of the incoming 738.8-nm beam to the TEM00 mode of the resonant cavity. The total optical-path length in the cavity is 36 cm, and the folding angle is about 5°. The 369.4-nm radiation generated in the crystal leaves the cavity immediately through mirror M4.

The position of flat mirror M2 is varied by use of a piezoelectric transducer under feedback control to maintain the resonant frequency of the cavity in lock with the frequency of the 738.8-nm radiation from the laser diode. The feedback is supplied by a polarization-detection scheme: Light reflected and transmitted via mirror M1 outward from the folded-ring resonant cavity consists of a superposition of samples of the incoming and the intracavity resonating 738.8-nm beams respectively. This superposition sample beam passes through a quarter-wave plate oriented at 45° and a beam splitter cube, the two polarization outputs of which are fed to two photodiodes. A deviation from resonance gives rise to elliptical polarization, the degree and handedness of which are related directly to the amount and sign of the deviation and to the outputs of the photodiodes. The outputs of the photodiodes are processed via feedback circuitry, which applies the appropriate corrective signal to the piezoelectric transducer to minimize the deviation from resonance.

This work was done by Angelyn P. Williams and Lutfollah Maleki of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 12*** *on the TSP Request Card.*
NPO-19096

Estimating Slopes in Images of Terrain by Use of BRDF

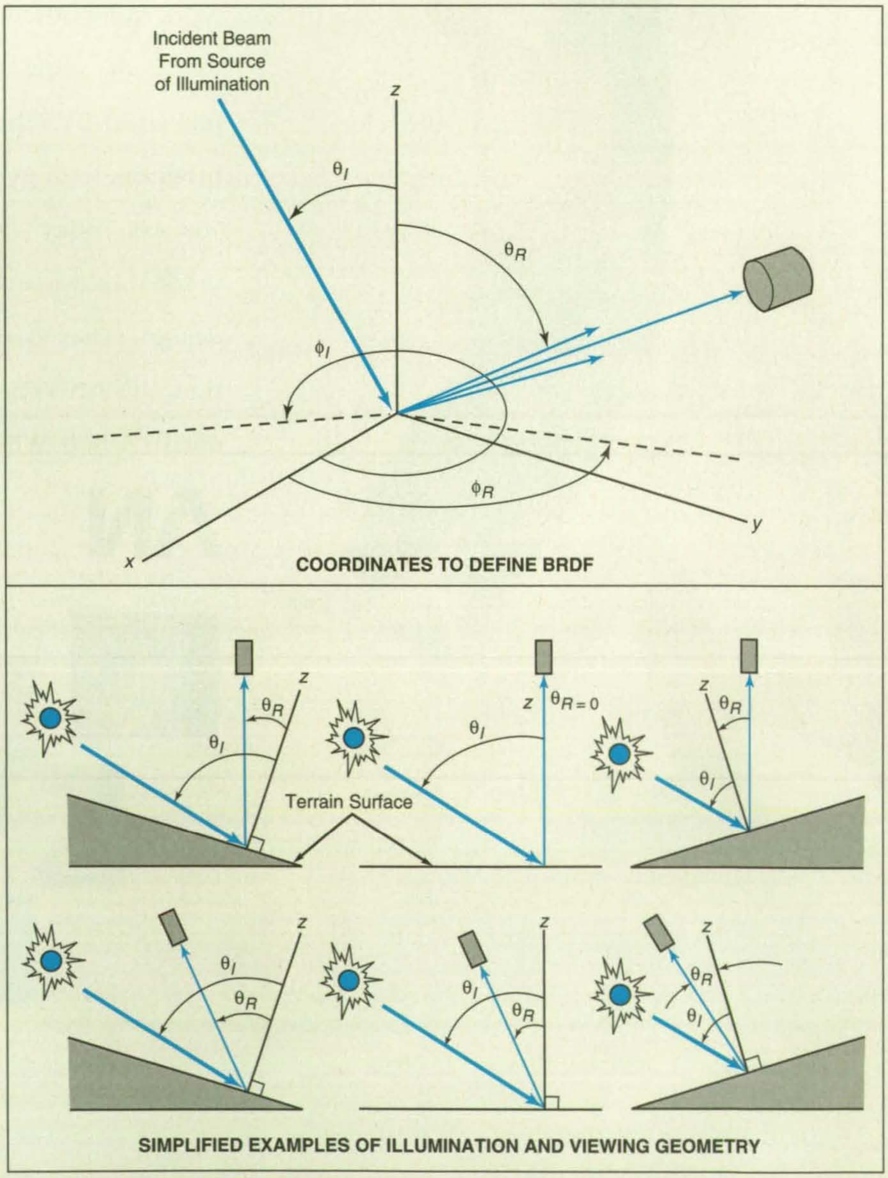
This method would work at almost all combinations of illumination and viewing angles.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed method of estimating slopes of terrain features is based on the use of the bidirectional reflectivity distribution function (BRDF) in analyzing aerial photographs, satellite video images, or other images produced by remote sensors. The estimated slopes could be integrated along horizontal coordinates to obtain estimated heights; thus, one could generate three-dimensional terrain maps (e.g., topographical maps). Unlike the well-known stereoscopic method, this method would not require coregistration of terrain features in pairs of images acquired from slightly different perspectives. Unlike the well-known method of estimating heights of terrain features from shadows, this method would not require the Sun or other source of illumination to be low in the sky over the terrain of interest. On the contrary, it would be best when the Sun was high.

The figure illustrates the geometric relationships among a source of illumination, an illuminated surface, and a camera or other imaging detector. The x and y axes of a Cartesian coordinate system lie on the surface, while the z axis is perpendicular to the surface (and is not necessarily vertical because the surface could be sloping). A beam of light from the source of illumination is incident at angle θ_I with respect to the z axis, and the plane of incidence lies at angle ϕ_I in the x–y plane. The imaging detector views light reflected at angle θ_R with respect to the z axis in a plane of reflection at angle ϕ_R in the x–y plane.

The BRDF specifies the fraction of incident illumination reflected toward the detector for a given combination of θ_I, ϕ_I, θ_R, ϕ_R. Because the BRDF explicitly incorporates all of the relevant angu-



The **Orientations of the Illumination, Surface, and Imaging Detector** determine the local relative brightness of the scene as viewed by the imaging detector: this relationship is expressed in the BRDF.

lar dependences, there would be no preferred viewing or illumination angles as there are in the stereoscopic and shadow methods; instead, the proposed method would work well at almost all combinations of illumination and viewing angles. The method can be summarized as follows: Assuming that the reflective characteristics remain the same over terrain areas at least several pixels wide, one could, in principle, use the BRDF to deduce slopes in the pixels from interpixel variations in observed radiometric characteristics of the terrain.

The BRDF of the terrain surface of interest can be obtained by direct measurement, approximated by extrapolation or interpolation of BRDFs from nearby areas, or approximated by use of a mathematical model. One of the advantages of the proposed method is that even approximate BRDFs would yield useful estimates of slopes: this is partly because most assumptions regarding physical processes that govern reflection result in smoothly varying BRDFs. Thus, a slightly erroneous BRDF would yield small errors in the distribution of heights, but the locations of changes in height would still be indicated accurately. Once accurate BRDF data were acquired, initial estimates of heights made with approximate BRDFs could be refined.

This work was done by Marija S. Scholl of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 13*** *on the TSP Request Card. NPO-19133*

Apparatus Tests Thermocouples for Seebeck Inhomogeneity

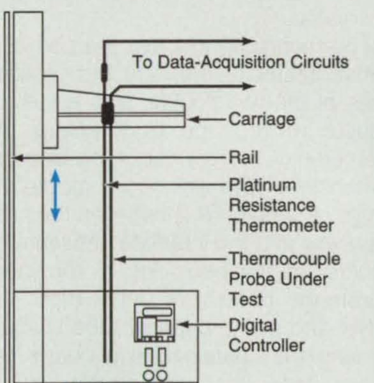
This automated apparatus reveals sources of error that are not revealed in calibration.

Langley Research Center, Hampton, Virginia

A computer-controlled, automated apparatus detects and measures Seebeck inhomogeneities in sheathed thermocouples. Seebeck inhomogeneities are abnormal spatial variations in the Seebeck coefficients of materials, which can give rise to errors in thermocouple readings, as explained below. The apparatus is a prototype for development of a standard method and equipment for routine acceptance/rejection testing of sheathed thermocouples in industrial and research laboratories.

In the case of a thermocouple conductor, a Seebeck inhomogeneity typically arises from an unintended lengthwise variation in chemical composition and/or a variation in microstructure caused by crimping, kinking, or excessive bending. When a thermocouple is operated in an environment in which a gradient of temperature along its conductors overlaps a Seebeck inhomogeneity, the Seebeck effect in the overlap region can contribute an erroneous component to the output of the thermocouple. Ordinary calibration measurements do not provide data on Seebeck inhomogeneities.

The basic idea of the apparatus is to measure the output voltage of a thermocouple probe oriented along a sharp gradient of temperature between two



This **Apparatus Acquires Data on Seebeck Inhomogeneities** in the thermocouple under test: It measures the thermocouple output voltage as a function of the position of the probe along a sharp gradient of temperature. Abnormal variations in the voltage-versus-position data are indicative of Seebeck inhomogeneities.

temperature zones, and to repeat the measurement at many increments of position along the gradient to obtain highly spatially resolved data from which the Seebeck inhomogeneities can be quantified. The higher-temperature zone (temperature ≤225 °C) is established by a regulated-temperature heated bath of silicone oil containing a central well filled with a molten eutectic mixture of gallium, indium, and tin. The lower-temperature zone is established by ambient air. To maintain the desired sharp, well-defined gradient of temperature between the two zones, ambient air is forced through ports in an insulating fixture that floats on top of the eutectic mixture in the heated bath.

The thermocouple under test, accompanied by a platinum resistance thermometer that provides reference temperature measurements, is lowered into the eutectic mixture. To obtain the desired controlled vertical motion, the upper ends of the thermocouple and platinum resistance thermometer are attached to a carriage that is moved along a vertical rail by a lead-screw-type mechanism driven by a stepping motor under computer control. The carriage is moved intermittently in repeated abrupt increments as small as 1/787 mm alternated with brief holding periods, during which the measurements are taken. The measurements are correlated automatically with the increments of position. Depending on the frequency of repetition, the average speed ranges from 0.001 in. (25.4 μm) per second to 5 in. (12.7 mm) per second. Optionally, the carriage can be lowered in a continuous motion, in which high-resolution position data are not correlated automatically with the thermocouple readings.

This work was done by Cecil G. Burkett, Jr., Willard A. Bauserman, Jr., and James W. West of **Langley Research Center.** *For further information,* ***write in 289*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-15198.

Measuring Interfacial Tension Between Immiscible Liquids

A capillary-tube technique can be used for both equal-density and unequal-density liquids.

Lewis Research Center, Cleveland, Ohio

The figure illustrates the use of a glass capillary tube in a technique for measuring the interfacial tension between two immiscible liquids. The technique yields useful data over a fairly wide range of interfacial tensions, both for pairs of liquids that have equal densities and pairs of liquids that have unequal densities. Data on interfacial tensions are important in diverse industrial chemical applications, including enhanced extraction of oil; printing; processing foods; and manufacture of paper, emulsions, foams, aerosols, detergents, gel encapsulants, coating materials, fertilizers, pesticides, and cosmetics.

The technique involves the use of a cathetometer to measure the capillary rises of the two liquids, plus a stereoscopic microscope to measure the diameter of the capillary tube and the dimensions from which to compute the angle of contact (θ_{12}) between the capillary wall and the interface between the liquids. At the beginning of the measurement procedure, one dips the lower end of the capillary tube in liquid 1, which is contained in a quartz cell much wider than the capillary tube. Then one measures the capillary rise (h) of liquid 1. [Optionally, one could also measure the angle of contact (θ_{1a}) between the capillary wall and the upper surface of liquid 1, then use h and θ_{1a} in an independent calculation of the interfacial tension between liquid 1 and air.]

In the next step of the measurement procedure, one removes the capillary tube from liquid 1 without letting liquid 1 run out of the tube, then dips the lower end of the tube in liquid 2 (which is also contained in a wide quartz cell). Then one measures the combined capillary rises of both liquids in terms of the height (h_1) of liquid 1 above liquid 2 and the height (h_2) of the liquid-1/liquid-2 interface above the liquid-2/air interface (see figure). At this point, one also mea-

sures the dimensions to compute θ_{12}.

To ensure accurate readings, the glass capillary tube and the quartz cells must be kept scrupulously clean. For this purpose, they are washed, rinsed with solvents, rinsed with distilled water, and dried in a vacuum oven before placing them in contact with the liquids.

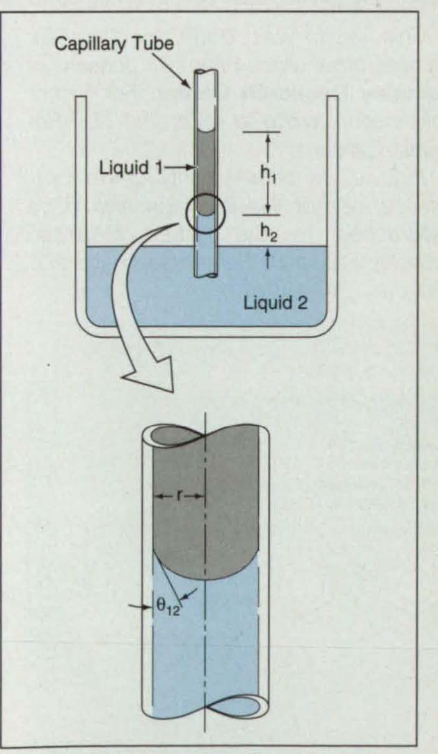
The interfacial tension (σ_{12}) between liquids 1 and 2 is calculated from the measurements by use of the following equation:

$$\sigma_{12} = gr\,[\rho_1(h_1 - h) + (\rho_2 h_2)]/(2\cos\,\theta_{12})$$

where g is the gravitational acceleration, r is the inner radius of the capillary tube, and ρ_1 and ρ_2 are the mass densities of liquids 1 and 2, respectively.

This work was done by Nasser Rashidnia of Sverdrup Technology, Inc., R. Balasubramaniam of Case Western Reserve University, and David M. Del Signore of the University of Toledo for **Lewis Research Center.** *Further information may be found in NASA CR-189133 [N92-21262/TB], "Interfacial Tension Measurement of Immiscible Liquids Using a Capillary Tube."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, User Services Division, Linthicum Heights, Maryland, Telephone No. (301) 621-0394. Rush orders may be placed for an extra fee by calling the same number.
LEW-15855



The **Combination of Capillary Rises** of two liquids and the interfacial contact angle are measured and used to calculate the interfacial tension.

Poly(arylene ether)s Containing Pendent Ethynyl Groups

Thermomechanical properties and resistance to solvents can be enhanced.

Langley Research Center, Hampton, Virginia

Poly(arylene ether)s that contain pendent ethynyl groups have been synthesized. These poly(arylene ether)s offer an advantage over linear poly(arylene ether)s in that upon heating, the pendent ethynyl groups react to form cross-linked molecular structures that exhibit greater resistance to solvents and higher glass-transition temperatures and tensile moduli. These polymers are useful as adhesives, moldings, films, and matrices of composite materials.

Poly(arylene ether)s are condensation polymers that can be prepared by various routes. The most popular route taken heretofore, which is the one of interest here, involves the reaction of an aromatic bisphenol with an activated aromatic dihalide to form a poly(arylene ether), which has a repeating molecular unit of the general type

(—O—Ar—O—Ar′—), where

- Ar denotes a divalent aromatic radical that comes from the aromatic bisphenol, and
- Ar′ denotes another divalent aromatic radical that comes from the aromatic dihalide and contains an electron-withdrawing activating group para to the halide to be displaced.

In the present case, the aromatic bisphenol is one in a class of newly synthesized compounds that contain pendent ethynyl groups. Figure 1 illustrates the synthesis. Figure 2 illustrates the reaction of one of these ethynyl-containing aromatic bisphenols with an activated difluoro monomer to obtain a poly(arylene ether) with pendent ethynyl groups.

The poly(arylene ether)s that contain pendent ethynyl groups offer advantages over acetylene-terminated arylene ether (ATAE) oligomers:

- Even before heating and the resultant cross-linking, the poly(arylene ether)s containing pendent ethynyl groups have high molecular weights and can be formed into tough films. The lower-molecular-weight ATAE's typically form brittle films.
- The densities of cross-links in cured poly(arylene ether)s that contain pendent ethynyl groups can be controlled by copolymerizing bisphenols that contain pendent ethynyl groups with other bisphenols that do not, to form polymers with high molecular weights. In contrast, the densities of cross-links in ATAE's can be varied only by changing the molecular weights of the oligomers, with possible adverse effects on the ability to make films and moldings.

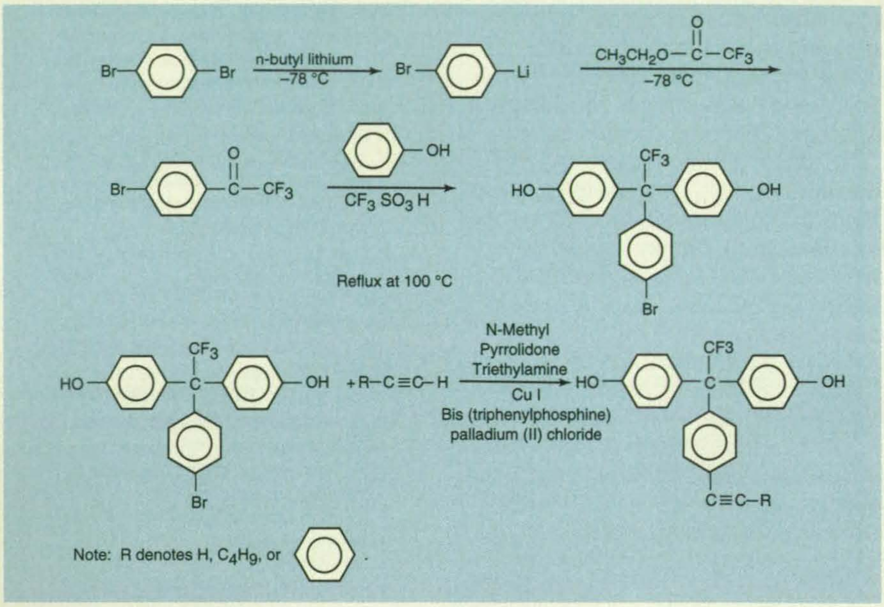


Figure 1. **Aromatic Bisphenols** that contain pendent ethynyl groups are synthesized for use in making poly(arylene ether)s that can be cross-linked by reaction of the pendent ethynyl groups.

This work was done by Paul M. Hergenrother and Brian J. Jensen of **Langley Research Center.** *For further information,* ***write in 48*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-15041

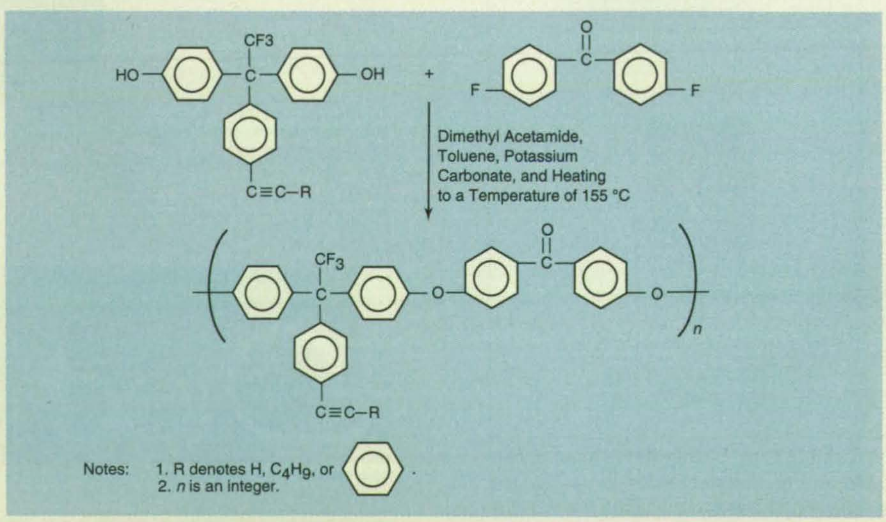


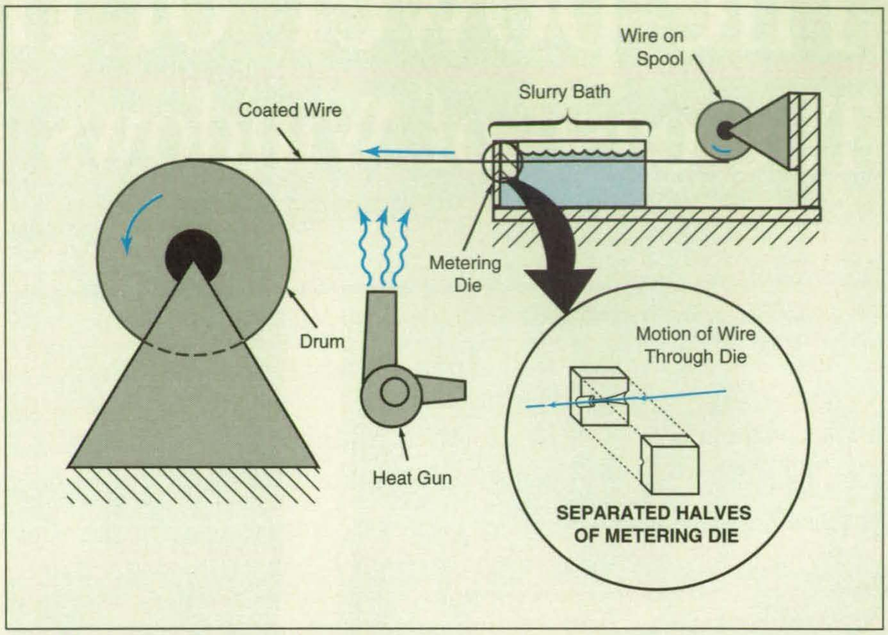
Figure 2. A **Poly(arylene ether)** that contains pendent ethynyl groups is made by reacting an activated difluoro monomer with an aromatic bisphenol that contains pendent ethynyl groups.

Forming Refractory Insulation on Copper Wire

Wire coated with flexible, uncured refractory material can be formed into coils.

Lewis Research Center, Cleveland, Ohio

Flexible organic coating materials commonly used to insulate copper wires cannot withstand long-duration exposure to temperatures above 250°C. An alternative insulating process (illustrated schematically in the figure) forms a flexible coat of uncured refractory insulating material on a copper wire. The coated wire can be formed into a coil or other complex shape. When subsequently cured to its final brittle form, the insulating material can withstand temperatures above the melting temperature of the wire. This process could be used to make coils for motors, solenoids, and other electrical devices that are to be operated at high temperatures.



The **Wire-Coating Apparatus** forms a "green" coat on the copper wire. After the wire is coiled, heating converts the "green" coat to a refractory electrical insulator.

In the coating process, the wire is pulled through a slurry of the precursor materials, then pulled through a die to control the coating thickness, then wound on a drum, and finally dried under an infrared lamp. Because the uncured, or "green," coats formed by this process are not sufficiently durable to withstand the handling and bending required to form the wire into a coil of complex shape, two methods were developed to increase the durability of the green coats: The first method is to spray the dried, green coat with a dilute polymer solution before removing the coated wire from the drum. Best results are obtained from three applications of the polymer solution, with drying under an infrared lamp after each application. The second method is to mix a polymer latex into the precursor slurry in which the wire is dipped.

Both methods result in a green coating that does not crack or peel off when coils are wound. The adhesive properties of the green coating can be controlled by selection of the type of polymer used. If needed, potting compounds can be applied to the coil before curing.

The coated coil is cured at 350°C to burn off the polymer. After curing, a thin, rigid, insulating refractory coat remains on the wire.

This process was used to make copper coils for a high-temperature nuclear-magnetic-resonance probe. The slurry was made by adding 28 percent of Gentac 118 latex (41.5 percent solids) to Aremco 571 ceramic cement. This coating material is chemically compatible with copper and has a coefficient of thermal expansion close to that of copper. The cured coating remained intact after repeated thermal cycling.

This work was done by J. Setlock and G. Roberts of **Lewis Research Center.** *No further documentation is available.*
LEW-15730

Coatings Would Protect Polymers Against Atomic Oxygen

Silver oxide would catalyze the recombination of atomic oxygen into molecular oxygen.

Lewis Research Center, Cleveland, Ohio

A proposed interposition of layers of silver oxide tens to hundreds of angstroms thick between polymeric substrates and overlying films (see Figure 1) is expected to help protect the substrates against chemical attack by monatomic oxygen. In the original intended application, the polymer substrate would be, typically, a sheet of polyimide that supports an array of solar photovoltaic cells on a spacecraft in a low orbit around the Earth. Presumably, the concept would also be applicable to the protection of equipment in terrestrial laboratory and industrial vacuum and plasma chambers in which monatomic oxygen is present.

Materials that are suitable as overlying coats to protect against monatomic oxygen include SiO_x (where $1.9 \le x \le 2.0$), SiO_2 filled with fluoropolymer(s) for flexibility, and Al_2O_3. However, defects in films made of these materials allow monatomic oxygen to react with the underlying materials, gradually producing cavities centered around the original defect sites. A cavity traps some of the impinging atomic oxygen, increasing its opportunity to attack the organic substrate. In a coating of the proposed type, a thin film metal or metal oxide catalyst adjacent to the organic substrate would catalyze the recombination of monatomic oxygen into molecular oxygen, which is much less chemically reactive. Thus, the catalyst layer would help reduce the growth of the cavity and thereby reduce the rate of attack of the organic substrate by atomic oxygen.

Figure 2 shows a reel-to-reel coating system that could apply a catalyst interfacial layer followed by an SiO_x protective layer. In this example, two radio-frequency magnetron sputtering sources are shown—one for each of the coating layers. Alternatively, one could use a single radio-frequency magnetron to deposit a single protective coat if the sputtering target contained a mix of silicon dioxide and catalyst: this should result in a film containing a uniform composition of catalyst distributed in its bulk. Another alternative process would involve electron-beam evaporation from a crucible of catalyst metal or metal oxide followed by electron-beam evaporation from a crucible of silicon dioxide or silicon monoxide. Other alternative deposition processes could include chemical-vapor deposition or reactive sputter deposition.

Several alternative compositions of coating layers may be fea-

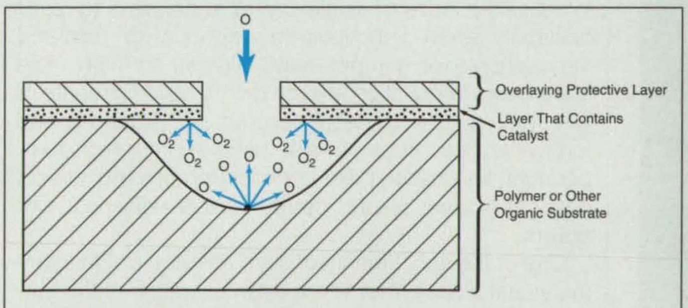


Figure 1. The **Interfacial Layer Containing a Catalyst** would cause the recombination of monatomic oxygen into molecular oxygen, thereby helping to protect the substrate from attack by monatomic oxygen.

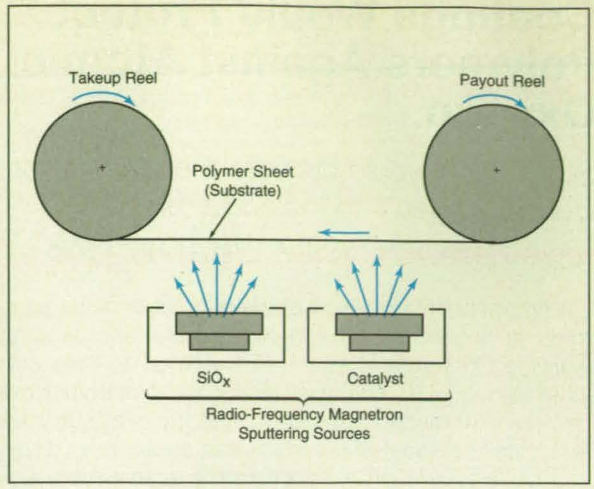


Figure 2. The **Interfacial Layer Could Be Applied** by radio-frequency magnetron sputtering, followed immediately by similar application of the overlying protective layer.

sible. Instead of pure silver metal or metal oxide, the interfacial layer could consist of a mixture of catalyst materials. The bulk of the outermost protective layer could consist of any metal oxide or of metal oxide mixed with fluoropolymers; it could also contain some catalyst. Materials such as silver oxide, gold, nickel, and hafnium have been reported to be effective catalysts to recombine atomic oxygen.

This work was done by Bruce A. Banks and Sharon K. Rutledge of **Lewis Research Center**. *For further information,* ***write in 20*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Lewis Research Center [see page 20]. Refer to LEW-15306.

Hydrogen Annealing of Single-Crystal Superalloys

Sulfur is removed, with consequent increase in resistance to oxidation at high temperatures.

Lewis Research Center, Cleveland, Ohio

Annealing at a temperature ≥ 2,200°F (>~ 1,200°C) in an atmosphere of hydrogen has been found to increase the ability of single-crystal superalloys to resist oxidation when subsequently exposed to oxidizing atmospheres at temperatures almost as high. The superalloys in question are the principal constituents of hot-stage airfoils (blades) in aircraft and ground-based turbine engines; they are also used in other high-temperature applications like chemical-processing plants, coal-gasification plants, petrochemical refineries, and boilers.

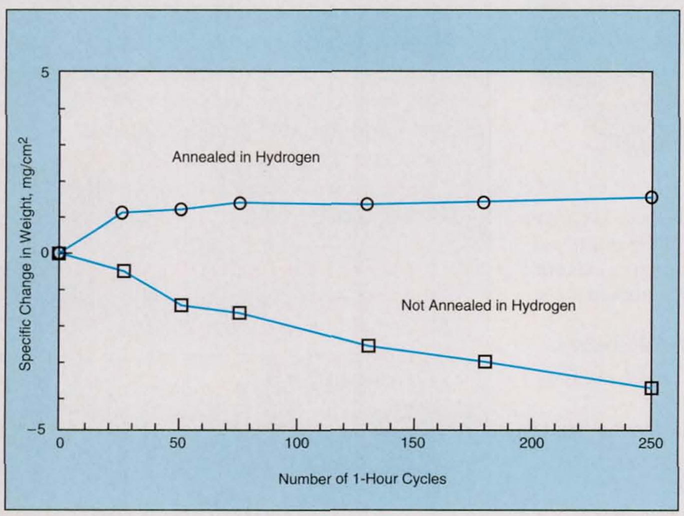
One of the constituents of such an alloy is aluminum: the alumina scale that forms upon oxidation of the surface of the alloy acts as a barrier to the diffusion of oxygen, thereby retarding the further oxidation of the underlying bulk of the alloy. The alloy also contains sulfur impurities (typically at a concentration about 10 parts per million). Sulfur degrades resistance to oxidation in the following way: when thermally activated, the

sulfur segregates to free surfaces in concentrations of as much as 50 atomic percent. The sulfur concentrated at the interface between the metal and the protective oxide scale decreases the adhesion of the scale, thus increasing the tendency toward spallation of the scale, with consequent decrease in resistance to oxidation. The degradation becomes more severe when the exposure to the oxidizing atmosphere includes cycles of heating and cooling.

The hydrogen anneal removes most of the sulfur. First, the heating accelerates the segregation of sulfur to the outer surface. Then the chemical reaction between the hydrogen atmosphere and the sulfur at the surface removes the sulfur by forming hydrogen sulfide gas. In a demonstration, turbine blades of cast René N5 single-crystal superalloy were annealed in hydrogen at 2,340°F (1,282°C) for 100 h, reducing the sulfur content from 6 to 0.3 parts per million. Then both the hydrogen-annealed blades and a set of blades that had not been so treated were exposed to 250 1-h cycles of oxidation at 2,100°F (1,149°C). The results shown in the figure indicate the greater ability of the hydrogen-annealed specimens to withstand cyclic oxidation.

Heretofore, most research into the protection of superalloys against oxidation has focused on coating processes, which increase cost and weight and decrease the fatigue strengths of the protected parts. Other research has focused on the incorporation of alloy constituents that react with sulfur to increase the adherence of oxide scales. The hydrogen anneal provides resistance to oxidation without decreasing fatigue strength and without need for coating or for reactive sulfur-gettering constituents. Also in comparison with coating, hydrogen annealing costs less; the saving can amount to about $75 per turbine blade or $15,000 per turbine engine (1992 prices). The benefits of hydrogen annealing may also extend to stainless steels, nickel/ chromium, and nickel-base alloys, which are subject to the same scale-adhesion and oxidation-resistance considerations, except that the scale is chromia instead of alumina.

This work was done by James L. Smialek of **Lewis Research Center** *and John C. Schaeffer and Wendy Murphy of General Electric Co. For further information,* ***write in 9*** *on the TSP Request Card.*
LEW-15771



The **Specimens Annealed in Hydrogen** gained about 1 mg/cm^2 at 2,100 °F and thereafter retained most of the gain, indicating the formation and retention of protective oxide scale. The specimens that had not been annealed lost about 4 mg/cm^2, indicating that spallating took place during repeated cycling.

Carbon-Fiber/Epoxy Tube Lined With Aluminum Foil

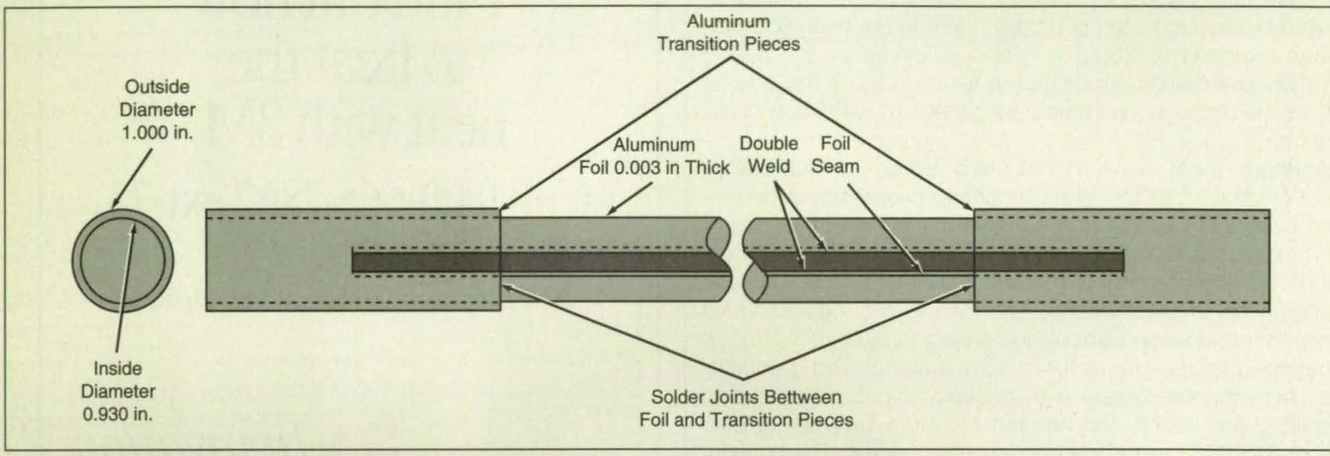
The liner provides the impermeability needed to contain ammonia.

Marshall Space Flight Center, Alabama

A carbon-fiber/epoxy composite tube lined with a welded aluminum foil would be useful as part of a lightweight heat pipe in which the working fluid is ammonia. Similar composite-material tubes lined with foils could also be incorporated into radiators, single- and two-phase thermal buses, tanks for the storage of cryogenic materials, and other plumbing that is required to be lightweight.

As illustrated schematically in the figure, the liner consists of aluminum foil 0.003 in. (about 0.08 mm) thick that is rolled into a cylinder, the seam of which is welded by a proprietary technique. Each end of the foil tube is soldered to a short section of thicker-walled aluminum tube that serves as a transition piece for connection to another plumbing component. The welds and solder joints provide leak-tight seals to the foil tube.

The aluminum liner provides impermeability for a vacuum seal, to contain the ammonia in the heat pipe, and to prevent the flow of noncondensable gases into the heat pipe. The liner is needed in this regard because the composite material



The **Aluminum Foil Liner and Transition Pieces** are welded and soldered into a single leaktight unit.

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is slightly porous. The liner is also needed to prevent contact between the ammonia and the composite material of the tube because the ammonia and the epoxy in the composite material are not chemically compatible with each other.

The composite material is formed on the outside of the foil tube and transition pieces by use of either the wet-filament-winding (WFW) process or, preferably, the resin-transfer-molding (RTM) process. The RTM process begins with braiding of dry carbon fibers over the liner, which is supported internally by a mandrel.

The fiber-covered liner is placed in a vacuum-tight clamshell aluminum mold, which is then evacuated. The epoxy resin is injected into the mold by use of pressure and vacuum. The epoxy is cured, the tube thus formed is taken out of the mold, and the mandrel is removed.

The tube can be joined or sealed to other tubes by conventional welding at the transition pieces. The prototype tube is 1 in. (about 25 mm) in diameter with a wall 0.020 in. (about 0.51 mm) thick and weighs 17 g/ft (about 56 g/m). An aluminum tube of comparable strength weighs approximately 46 g/ft (about 151 g/m).

This work was done by Nelson J. Gernet and Gregory K. Kerr of Thermacore, Inc., for **Marshall Space Flight Center.** *For further information,* ***write in 27*** *on the TSP Request Card.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Marshall Space Flight Center [see page 20]. Refer to MFS-26237

Galvanic Protection of 2219 Al by Al/Li Powder

Al/Li could replace chromium, which is a suspected carcinogen.

Marshall Space Flight Center, Alabama

Coatings that consisted of aluminum/lithium powders incorporated into an acrylic resin were found to protect panels of 2219 aluminum from corrosion by salt spray better than did a coating that consisted of 2219 aluminum in the same acrylic resin. The exact mechanism by which the aluminum/lithium coatings protect against corrosion is unknown, although a galvanic mechanism is suspected. These coatings (instead of chromium) might be applied to fasteners and bars to provide cathodic protection, both with and without impressed electrical current.

Heretofore, chromium has been used to protect 2219 aluminum (which is rapidly corroded because of its high copper content) in aerospace applications. Until now, chromium was the only coating material known to be capable of inhibiting salt-spray corrosion of this aluminum alloy. Unfortunately, chromium is a suspected carcinogen.

Fine powders (100 to 300 mesh) of 2219 aluminum, Alcoa 2090 aluminum/lithium, and Reynolds Weldalite 049 aluminum/lithium were each incorporated into an acrylic resin and each used to coat six 4- by 6-in. (10- by 15-cm) panels of 2219 aluminum. The panels were dried, three panels with each coating were exposed to salt fog, and

For More Information Write In No. 411

three panels with each coating were exposed to humidity.

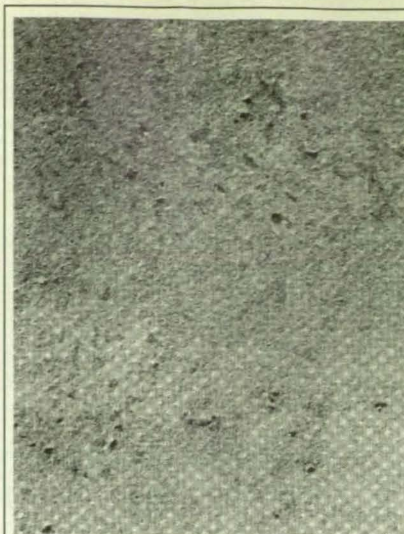
The coatings of the samples exposed to salt fog were removed after 264 hours of exposure. At that time, the panel coated with 2219 aluminum powder in acrylic was heavily pitted, whereas the panel coated with Alcoa 2090 aluminum/lithium had only a few pits, and the panel coated with Weldalite 049 aluminum/lithium, although discolored, had very few pits (see figure). There was no visible corrosion on any of the samples after exposure to humidity for 672 hours.

This work was done by Alfred Daech of Martin Marietta Corp. for **Marshall Space Flight Center.** *For further information,* ***write in 129*** *on the TSP Request Card.*

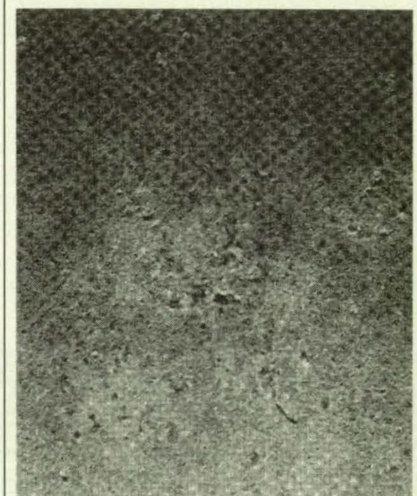
Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)], to the Martin Marietta Corporation. Inquiries concerning licenses for its commercial development should be addressed to

Martin Marietta Corp.
P.O. Box 179
Denver, CO 80201

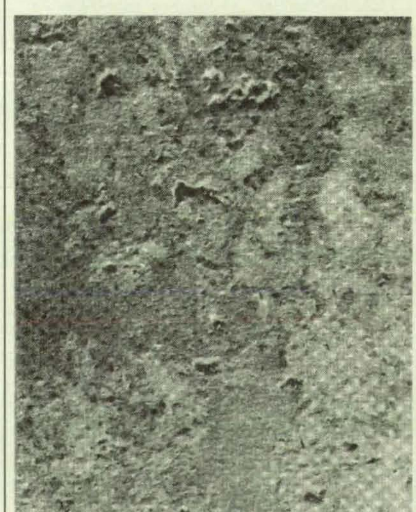
Refer to MFS-28713, volume and number of this NASA Tech Briefs issue, and the page number.



Corroded Surface That Had Been Coated With Weldalite 049 Aluminum/Lithium Powder in Acrylic



Corroded Surface That Had Been Coated With Alcoa 2090 Aluminum/Lithium Powder in Acrylic



Corroded Surface That Had Been Coated With 2219 Aluminum in Acrylic

The Panels Coated With Aluminum/Lithium Powder in Acrylic corroded less in salt fog than did the one coated with 2219 aluminum powder in acrylic.

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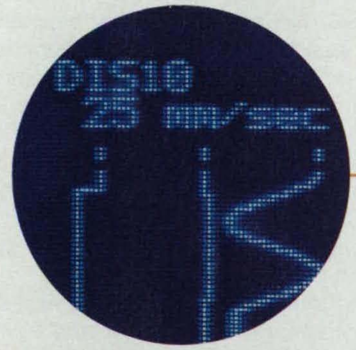

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Computer Program

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Computer Programs

These programs may be obtained at a very reasonable cost from COSMIC, a facility sponsored by NASA to make computer programs available to the public. For information on program price, size, and availability, write in the reference number on the TSP and COSMIC Request Card in this issue.

Mechanics

Interactive Software for Astrodynamical Calculations

Outputs can be plotted in a variety of formats on a variety of terminals.

The QUICK computer program provides the user with the facilities of a sophisticated desk calculator that can perform scalar, vector, and matrix arithmetic; propagate conic-section orbits; determine planetary and satellite coordinates; and perform other related astrodynamic calculations within a FORTRAN-like software environment. QUICK is an interpreter, and therefore there is no need to use a compiler or a linker to run QUICK code.

The capabilities of QUICK include options for automated printing of results, the ability to submit operating-system commands on some systems, and access to a plotting software package (MASL) and a text-editor subprogram without having to leave QUICK. Mathematical and programming features of QUICK include the ability to handle arbitrary algebraic expressions, provision for the user to define functions in terms of other functions, built-in constants such as p, direct access to useful common areas, matrix capabilities, extensive use of double-precision calculations, and the ability to load user functions from a standard library automatically.

The MASL (the Multimission Analysis Software Library) plotting-software package, included in the QUICK software package, is a set of subroutines that are compatible with the FORTRAN 77 language and are designed to facilitate the plotting of engineering data by enabling programmers to write application programs that are independent of plotting devices. Its universality lies in the number of plotting devices it puts at the user's disposal. The MASL package of routines has proved very useful and easy to work with, yielding good plots for most new users on the first or second try. The functions provided include routines for creating histograms, "wire mesh" surface plots, and contour plots as well as normal graphs with a large variety of types of axes. The library contains routines for plotting on Cartesian, polar, log, Mercator, cyclic, calendar, and stereographic axes, and for performing automatic or explicit scaling. The lengths of the axes of a plot are completely under the control of the program using the library.

Programs written to use the MASL subroutines can be made to send output data to the plotters associated with the remote job entries on the Univac 1100s; an off-laboratory Calcomp COM plotter; the Calcomp 1055 plotter; the Hewlett-Packard 2648 graphics terminal; the HP 7221, 7475, and 7550 pen plotters; the Tektronix 40xx- and 41xx-series graphics terminals; the DEC VT125/VT240 graphics terminals; the QMS 800 laser printer; the Sun Microsystems monochrome display; the Ridge Computers monochrome display; the IBM/ PC color display; or a "dumb" terminal or printer. Programs using this library can be written so that they always use the same types of plotters, or they can allow the choices of types of plotters to be deferred until after execution.

QUICK is written in RATFOR for use on Sun4-series computers running SunOS. No source code is provided. The standard distribution medium for this program is a 0.25-in. (6.35-mm) streaming-magnetic-tape cartridge in UNIX tar format. An electronic copy of the documentation in ASCII format is included on the distribution medium. QUICK was developed in 1991 and is a copyrighted work with all copyright vested in NASA.

This program was written by Ronald S. Schlaifer, David L. Skinner, and Phillip H. Roberts of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 49*** *on the TSP Request Card.*
NPO-18685

Program for Analyzing Designs of Liquid-Propellant Rockets

ROCCID incorporates the best existing mathematical models of combustion performance and stability.

The Rocket Combustor Interactive Design Computer Methodology (ROCCID) computer program provides a standardized methodology, using state-of-the-art codes and procedures, for the analysis of the combustion performance and stability of a liquid-propellant rocket engine. ROCCID provides the combustion analyst with a software tool to analyze an existing combustor design (point-analysis option), or design a high-performance, stable combustor, given a set of input design requirements (point-design option). ROCCID was created by concatenating the best existing mathematical models of combustion performance and com-

bustion stability into one comprehensive design software tool. An interactive front end (IFE) has been incorporated to facilitate generation of input by the user, track user-input options, and display selected output data.

The IFE provides the user with a convenient interactive software tool for generation of input, creation of files, and display of output. Each input character is checked in the IFE for validity, and warnings are displayed when input errors are sensed. Replay files, which contain a record of all keystroke inputs, are created and maintained. These files can be edited and used as input for a subsequent session.

The point-analysis and point-design options provide access to a variety of combustion performance and combustion stability analysis models that were selected from an industry-wide inventory of existing mathematical models. These analysis models are contained within ROCCID in a modular format. This enables the user to gain access to specific models for a specialized subanalysis or to use two or more models that perform similar functions to define and resolve uncertainties in the particular area of the analysis. Modular construction also facilitates upgrading of ROCCID as new analysis models are developed or refined.

ROCCID is currently capable of analyzing mixed-element injector patterns containing impinging like and unlike doublet or triplet, nonimpinging shower head, shear coaxial, and swirl coaxial elements. The injector can consist of mixed elements in a pattern including core, baffle, barrier and fuel-film/cavity-cooling-element zones. However, only elements of one type can be specified in each zone. Real propellant properties of oxygen, hydrogen, methane, propane, RP-1, monomethyl hydrazine, and nitrogen tetroxide are included in ROCCID.

The analysis models in ROCCID can account for the influences on combustion stability of acoustic cavities, Helmholtz resonators, and radial thrust-chamber baffles. ROCCID also contains the logic to interactively create a combustor design which will meet input performance and stability goals. A preliminary design results from the application of historical correlations to the input design requirements. The steady-state performance and combustion stability of this design is evaluated by use of the analysis models, and ROCCID guides the user as to the design changes (including the design of stability aids) needed to satisfy the user's performance and stability goals. Output from ROCCID includes a file formatted as an input file for the standardized JANNAF engine performance prediction procedure, plus detailed reports on combustion performance and combustion stability calculations.

ROCCID is written in ANSI FORTRAN 77 and VAX FORTRAN for DEC VAX-series computers running VMS. Approximately 10 percent of the source code is written in VAX FORTRAN. ROCCID requires 7MB of random-access memory for execution. The standard distribution medium for this program is a 1,600-bit/in. (630-bit/cm), 9-track magnetic tape in DEC VAX BACKUP format. It is also available on a TK50 tape cartridge in DEC VAX BACKUP format. This program was developed in 1991.

This program was written by Mark D. Klem of **Lewis Research Center;** *Jeff A. Muss, Thong V. Nguyen, and Dick Walker of Gencorp; Curtis W. Johnson of Software and Engineering Assoc.; and James E. Giuliani of the Ohio Aerospace Institute. For further information,* ***write in 240*** *on the TSP Request Card.*
LEW-15114

Mechanics

Capacitive Position Sensor for Accelerometer

An ultrasensitive capacitive position sensor measures the deflection of the accelerometer spring.

NASA's Jet Propulsion Laboratory, Pasadena, California

A capacitive position sensor measures the displacement of the proof mass in a prototype accelerometer described in the preceding article, "Single-Crystal Springs for Accelerometers" (NPO-18795). The capacitive position sensor is an ultrasensitive, miniature device that operates at ultrahigh frequency and is described in more detail in "Ultra-High-Frequency Capacitive Displacement Sensor," (NPO-18675), NASA Tech Briefs, Vol. 18, No. 9, (September 1994), page 42.

By incorporating the low-loss single-crystal silicon spring and the miniature capacitive position sensor into the accelerometer, one obtains a compact, lightweight device (volume < 100 cm^3, mass < 120 g) that exhibits high sensitivity and a low noise floor. The accelerometer has a dynamic range of 10^9: it can measure accelerations from 10^{-9} to 1 x normal Earth gravitation.

The output of the capacitive position sensor is proportional to acceleration over a bandwidth from dc to the resonant frequency of the spring and proof mass (40 Hz). The coarse-approach screw shown in the figure of the preceding article is used to adjust the capacitor gap to maximize sensitivity.

This prototype accelerometer represents a significant improvement over older, highly sensitive accelerometers. For example, state-of-the-art seismometers of equivalent sensitivity are massive (on the order of 10 kg), fragile (not easily moved without recalibration), and large (approximately two orders of magnitude more volume). The advances in the design and fabrication of the prototype accelerometer should also be applicable to magnetometers and other sensors in which sensed quantities can be measured in terms of deflections of small springs.

This work was done by Thomas R. VanZandt, William J. Kaiser, and Thomas W. Kenny of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 138*** *on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

William T. Callaghan, Manager
Technology Commercialization
JPL-301-350
4800 Oak Grove Drive
Pasadena, CA 91109

Refer to NPO-18794, volume and number of this NASA Tech Briefs issue, and the page number.

Single-Crystal Springs for Accelerometers

Thermal noise is reduced, enabling the use of smaller proof masses.

NASA's Jet Propulsion Laboratory, Pasadena, California

Spring-and-mass accelerometers in which the springs are made of single-crystal material (originally, silicon) are being developed (see figure). In a spring-and-mass accelerometer, a proof mass is attached to one end of the spring, and acceleration of an object at the other end of the spring can be measured in terms of the deflection of the spring, provided that the frequency spectrum of the acceleration lies well below the resonant frequency of the spring-and-proof-mass system. The use of single-crystal spring materials instead of such polycrystalline spring materials as ordinary metals makes it possible to construct highly sensitive accelerometers (including seismometers) with small proof masses.

The polycrystalline materials used heretofore in accelerometer springs dissipate vibrational energy at fairly high rates. As a result, a conventional accelerometer has a relatively low Q. (Q, the mechanical quality factor, is the ratio between the resonant angular frequency of vibration and the rate of damping of the vibration of the spring-and-mass system.) Even when accelerometers with polycrystalline springs are mounted in vacuum to reduce viscous damping by air, they seldom exhibit *Q*'s greater than 40.

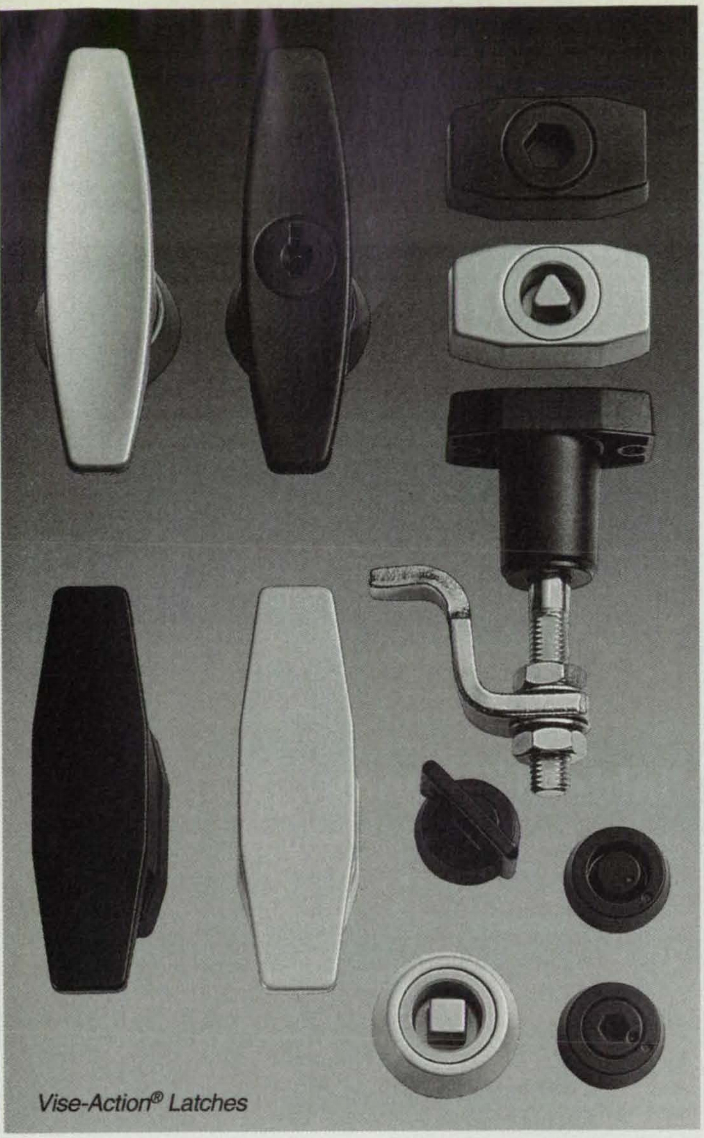
Thermally induced motion of the proof mass places a lower limit on the measurable acceleration. This lower limit is the thermal-noise-equivalent acceleration, which equals

$$\sqrt{\frac{4k_B T\omega_o}{mQ}}$$

where k_B is Boltzmann's constant, *T* is the absolute temperature, ω_0 is the resonant angular frequency, and *m* is the proof mass. Thus, low Q sets a high noise floor on the measurements.

The responsivity of an accelerometer — the ratio between deflection and acceleration — equals $1/\omega_0^2$. Thus, in the absence of noise and damping, one could obtain the same responsivity while reducing the total mass of the sensor by using a smaller proof mass and a less-stiff spring, provided that the mass and stiffness were reduced proportionally (because $\omega_0 = k/m$, where *k* is the stiffness). But in the presence of noise and damping, reduction of the proof mass increases the thermal-noise-equivalent acceleration, which thus places a lower limit on miniaturization.

To enable a further reduction in mass without an unacceptable increase in thermal-noise-equivalent acceleration, it is necessary to increase Q. Single-crystal materials offer the advantages of low damping (consequently, high Q) and low hysteresis. Established techniques for micromachining of single-crystal silicon enable the construction of small accelerometer struc-



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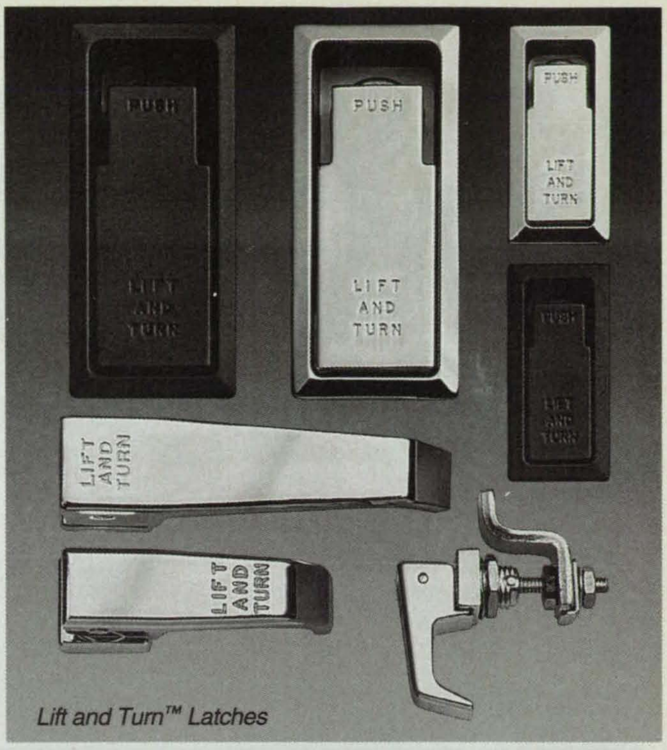

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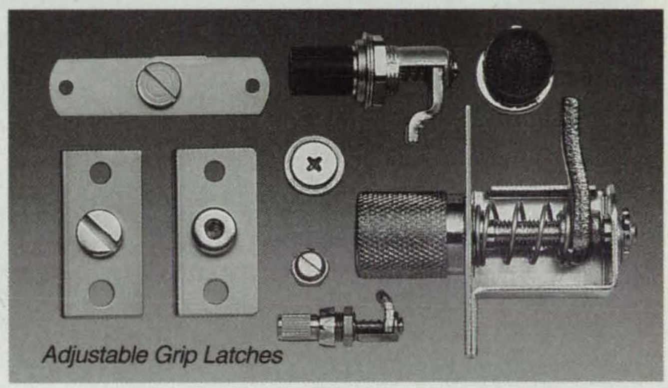

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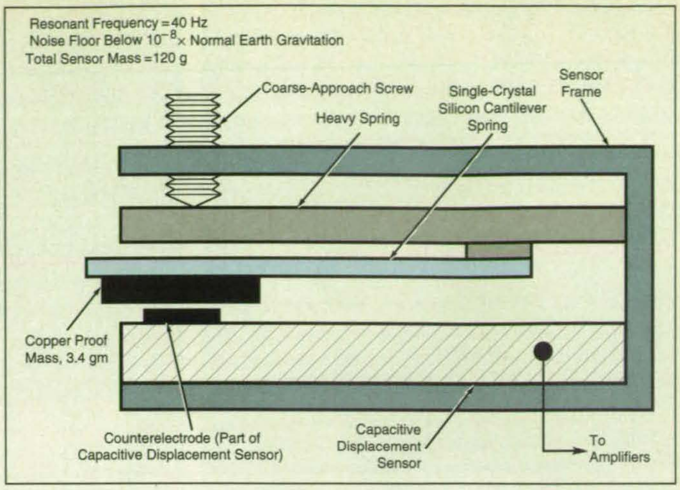
tures that can be tailored to specific requirements. By use of springs of single-crystal silicon, one can routinely obtain Q's of about 400 even in air, and Q's of more than 4,000 can be obtained in vacuum. Prototype units with proof masses of 3.4 g, spring constants of 215 N/m, and Q > 400 in air have been demonstrated. The thermal-noise-equivalent acceleration of these units is only about 2.2×10^{-10} times normal Earth gravitation in a 1-Hz bandwidth — much less than that achieved previously with such a small proof mass.

This work was done by Thomas R. VanZandt, William J. Kaiser, and Thomas W. Kenny of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 78*** *on the TSP Resquest Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

William T. Callaghan, Manager
Technology Commercialization
(M/S 79-23)
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109

Refer to NPO-18795, volume and number of this NASA Tech Briefs *issue, and the page number.*



This **Prototype Accelerometer** features a single-crystal silicon cantilever spring, which offers the advantages of high Q and low hysteresis. The deflection of the spring is measured by the capacitive motion sensor described in the following article.

Device Would Provide Controllable Buoyancy

Volume would adjust to provide required displacement.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed buoyant device would be attached to an object denser than water and adjusted to obtain neutral overall buoyancy. It could be used, for example, to support a marine environmental monitoring instrument at a fixed predetermined depth. In a marine salvage operation it could hold parts at a convenient depth before they are used or hoisted to the surface. The device was conceived to aid training astronauts in handling "weightless" equipment in water tanks.

The device would include an inflatable rubber bladder mounted on a plate (see figure). The bladder would contain an air valve and a pressure-relief disk that would rupture and release air if the bladder were inflated to excessive pressure. Air would be supplied to the air valve, above or below water, through a hose with quick-connect/disconnect fittings. The volume of the bladder could be adjusted by adjusting the pressure of air in the bladder while the bladder was submerged. For example, to maintain neutral buoyancy, it would be necessary to increase the interior pressure to compensate for higher ambient pressure at greater depths.

The device could be made in a variety of sizes and shapes to suit the objects to be supported. It could be equipped with such suitable attachment hardware as U-bolts, clamps, or cable ties. One or more such devices could be used to support an object as necessary.

The device could replace plastic foam floats, which must be cut to size according to estimates of the volume of foam that would give the required amount of buoyancy. Moreover, the device does not become waterlogged or release contaminating particles as foam sometimes does.

This work was done by Malcolm J. MacMartin of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 86*** *on the TSP Request Card. NPO-18829*

The **Inflatable Rubber Bladder** could be made in various lengths and widths.

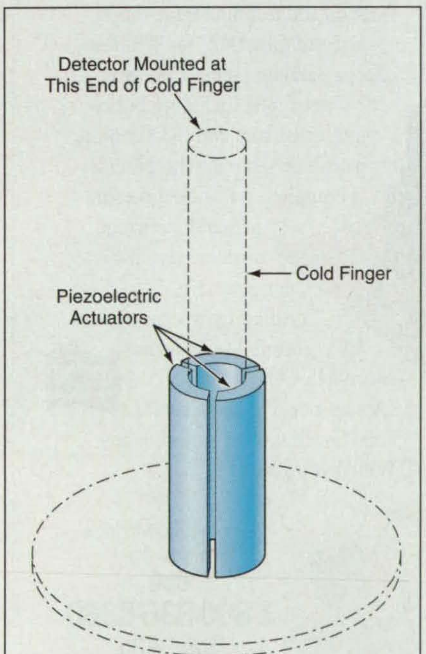
Piezoelectric Actuators on a Cold Finger

The actuators would be used to suppress vibrations.

NASA's Jet Propulsion Laboratory, Pasadena, California

A developmental system for active suppression of vibrations of a cold finger includes three piezoelectric actuators bonded to its outer surface (see figure). The cold finger in question is part of a cryogenic system associated with an infrared imaging detector. The cold finger supports and cools the detector. The position of the detector is required to be kept stable to within a few tenths of a micron. Variations in the pressure of the cryogenic fluid inside the cold finger create vibrations, causing the tip of the cold finger and the detector mounted on it to move over a range of 3 μm. When fully developed, the vibration-suppression system would be a feedback sensor/control/actuator system that would automatically adapt to the changing vibrational environment and suppress the pressure-induced vibrations by imposing compensatory vibrations via the actuators.

Each of the three actuators is a sector (of slightly less than 120°) of a cylinder of a piezoelectric ceramic. The radially inner and outer surfaces of each actuator are coated with conductive layers that act as electrodes. The actuators are placed at equal angular intervals around the cold finger and are bonded to the cold finger by an epoxy.



Three Piezoelectric Actuators are bonded to the cold finger near its base. These actuators can be used to suppress longitudinal and lateral vibrations of the upper end of the cold finger by applying opposing vibrations.

Because the ceramic material is relatively weak in tension, it is preferable to stretch the cold finger by pressurizing it during bonding, so that when bonding is complete and the pressure is released, the actuators are pre-stressed in compression.

The actuators are electrically insulated from each other by strips of dielectric film in the gaps between them. In operation, a voltage is applied to the electrodes of each actuator, causing its length to change slightly via the piezoelectric effect. The voltage applied to each actuator, and thus the change in its length, are independent of those of the other actuators.

Because the change induced by the actuators in the length of the cold finger is an average of the changes in

length induced by the individual actuators, longitudinal (lengthening/shortening) vibrations of the cold finger can be suppressed by applying a common voltage to all three actuators. Similarly, differences between the changes in length of different actuators cause bending of the cold finger. Thus, by adding an appropriate differential voltage to the common voltage applied to each actuator, lateral (bending) vibrations can also be suppressed.

This work was done by Chin-Po Kuo, John A. Garba, and Robert J. Glaser of Caltech for **NASA's Jet Propulsion Laboratory.** *For further information,* ***write in 277*** *on the TSP Request Card.* *NPO-19090*

Computing Contact Stresses in Gear Teeth

Friction and sliding are taken into account.

Lewis Research Center, Cleveland, Ohio

An improved method of computing the contact stresses in gear teeth accounts for complicating effects like those of static and sliding friction. In older methods (e.g., Hertzian analysis), these effects are ignored or else can be studied only with great difficulty. The improved method is based on equations and a computational procedure that incorporates these effects routinely.

The method is based partly on the equations, from the established theory of elasticity, for the distribution of stresses inside a solid object to which concentrated (point-contact) normal and tangential load forces are applied. The contact loads between two gear teeth can be represented as a distribution of

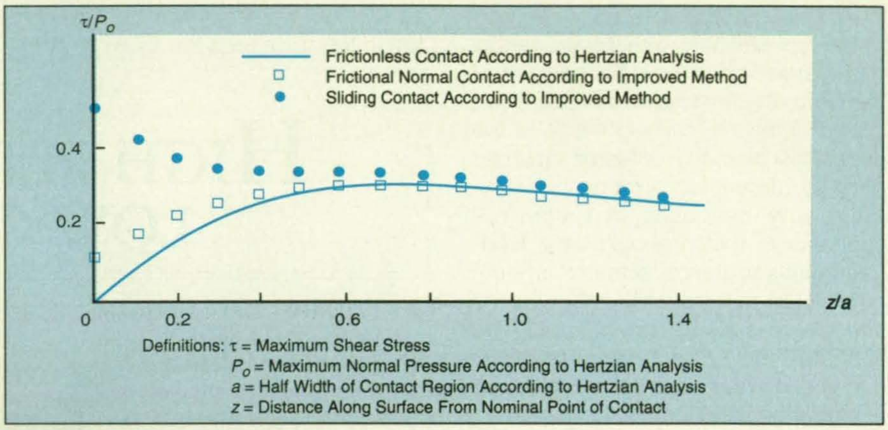


Figure 1. **Maximum Shear Stresses in an Aluminum Cylinder** pressed against a steel cylinder were computed by the improved method for sliding- and normal-contact cases and compared with the results of a Hertzian analysis.

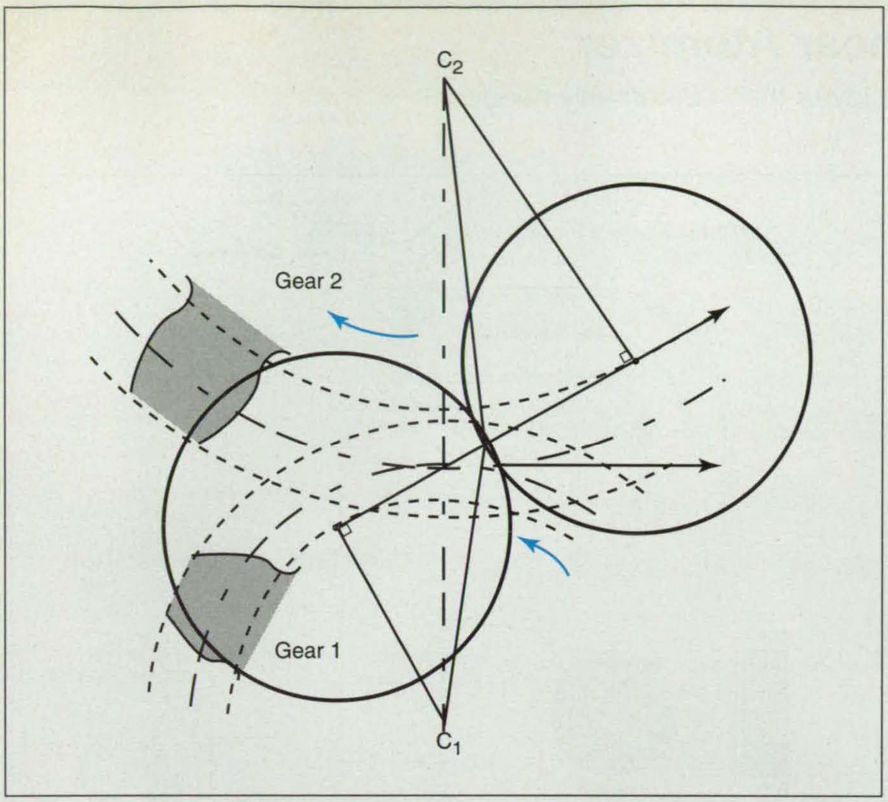


Figure 2. **Contact Stresses in Mating Gear Teeth** can be estimated as contact stresses in cylinders.

infinitesimal concentrated loads across the common contact surface for the purpose of exact mathematical integration, or else approximated as a collection of finite concentrated loads applied at nodal points for the purpose of numerical integration. Then invoking the principle of point-load superposition, the distribution of stresses and deformations of material at each point (or within each cell of a computational grid) in each tooth is computed as the sum of stresses and deformations produced by the point loads.

By incorporating tangential loads into the equations at the outset, this approach eliminates much of the difficulty of accounting for frictional forces, which are tangential loads. However, a new difficulty arises in that neither the extent of the contact region nor the "stick/slip" regions which produce static or sliding friction are known a priori. Accordingly, the improved method provides an iterative procedure for determination of the contact region and the nodal contact forces along with the contact stresses. The iterative procedure is as follows:

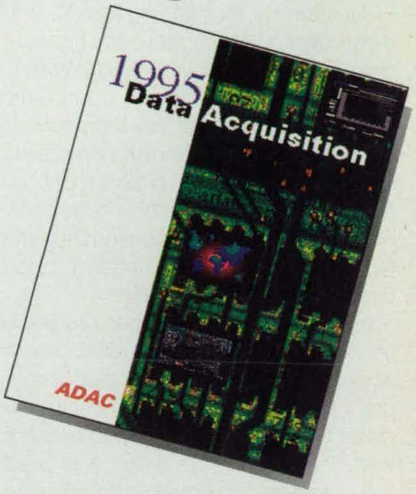
1. Assume a contact region.
2. Divide the assumed contact region into elements or cells.
3. Assume a stick region (in which the gear teeth do not slide against each other) within the contact region.
4. Solve the equations for the nodal contact forces.
5. Adjust the extent of the contact region by deleting nodes for which the computation in step 4 yielded negative normal forces (unrealistic local suction) between the teeth.
6. Adjust the stick region by use of the maximum frictional force that can be produced in the presence of a given normal force (i.e., check for slipping).
7. Repeat steps 1 through 6 until convergence is obtained.

Figure 1 shows some of the results obtained by applying this method to a steel cylinder pressed against an aluminum cylinder. To simplify the computations when applying this method to mating gear teeth, each tooth can be approximated as a cylinder with a radius equal to the radius of curvature of that tooth at its point of contact with the other tooth, as shown in Figure 2.

This work was done by Fred B. Oswald of **Lewis Research Center** *and Paisan Somprakit and Ronald L. Huston of the University of Cincinnati. Further information may be found in NASA TM-104397 [N91-22570], "Contact Stresses in Gear Teeth — A New Method of Analysis."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, Linthicum Heights, Maryland, Telephone No. (301) 621-0394. Rush orders may be placed for an extra fee by calling the same number.

LEW-15842



Fuel Injector With Shear Atomizer

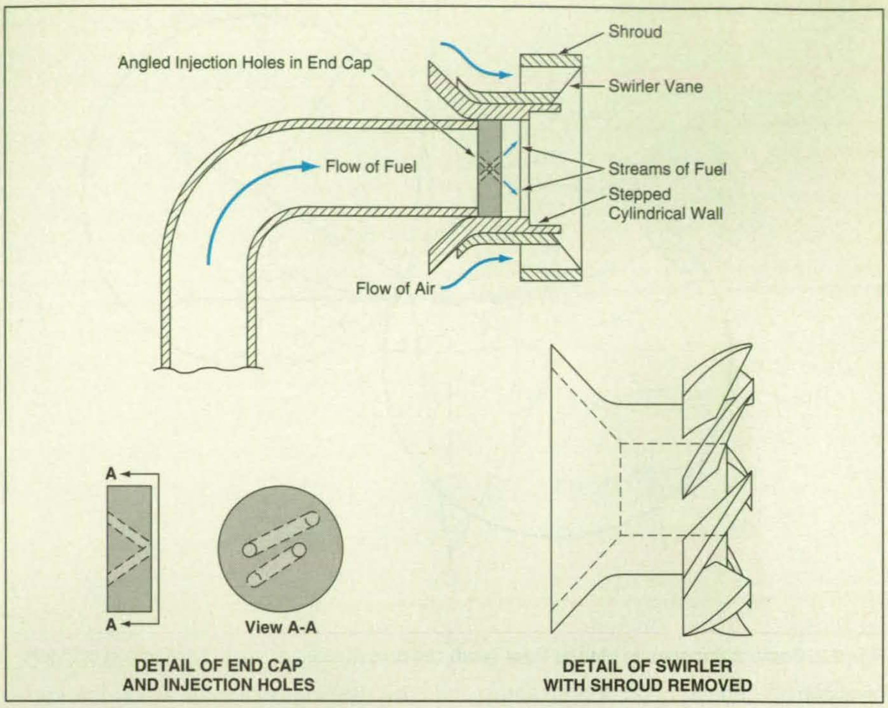
Fuel can be injected at a pressure lower than customarily needed.

Lewis Research Center, Cleveland, Ohio

An atomizer for injecting liquid fuel into a combustion chamber uses impact and swirl to break the incoming stream of fuel into small, more combustible droplets. In contrast, a representative conventional atomizer relies on passage of the liquid through a small orifice to produce droplets. Machining the orifice is expensive and time-consuming, and a high-pressure pump is needed to force the liquid through the orifice.

In the present atomizer, liquid fuel flows along a tube to an end cap that contains angled injection holes (see figure). The holes impart some swirl and direct the flow onto a stepped cylindrical wall. The impact upon the wall breaks the stream of liquid into droplets. Meanwhile, vanes in a shroud surrounding the stepped cylindrical wall impart swirl to inflowing air, and the resultant swirling flow of air entrains the droplets. Thus, the droplets are thoroughly mixed with air in preparation for combustion.

In tests, the fuel ignited and burned as well as or better than in the case of a



Slanted Holes direct the flow of liquid fuel to the stepped cylindrical wall. Impact on the wall atomizes the liquid. Air flowing past vanes entrains the droplets of liquid in a swirling flow.

conventional fuel atomizer. Moreover, the droplets were produced at one-fourth the fuel pressure needed in a conventional atomizer. Thus, much less energy is needed to pump the fuel.

This work was done by George W. Beal, Virgil L. Mills, Durward B. Smith II, and William F. Beacom of United Technologies Pratt & Whitney for **Lewis Research Center.** *For further information,* ***write in 187*** *on the TSP Request Card. LEW-15398*

Litter-Spinning Retarders

Aerodynamic plates would stop a litter from spinning during hoisting by a helicopter.

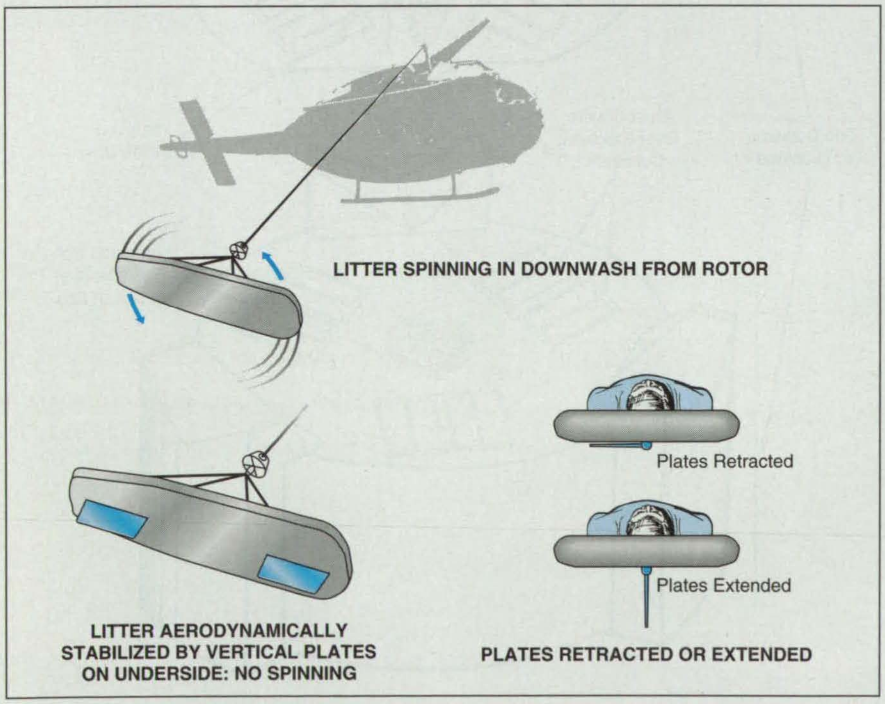
Langley Research Center, Hampton, Virginia

Basket litters used to hoist injured persons into helicopters would be equipped with vertical plates on their undersides to prevent spinning, according to a proposal (see figure). A litter suspended by a cable from a helicopter tends to spin because of aerodynamic effects caused mainly by the swirling downwash from the helicopter rotor. The vertical plates would provide aerodynamic stabilization against spinning via the combined actions of opposing aerodynamic torques and control of air-flow patterns around the litter. The feasibility of the concept was demonstrated in an experiment in which a 1/7-scale model of a litter with vertical cardboard tabs attached was stabilized against spinning in downwash from a fan that was aimed downward.

Spin is undesirable for several reasons: it complicates the work of the rescue crew, causes great discomfort to the person being lifted, and can even throw the injured person out of the litter, causing additional injuries. Heretofore, ropes have sometimes been tied to the ends of litters and held by ground attendants to prevent spinning, but this approach is disadvantageous in that attendants may sometimes be unavailable, and the ropes can become entangled in vegetation or other features of the terrain.

Features of the proposed litter-spinning retarders include convenience of deployment and independence from ground restraint. The retarder plate(s) could be folded flat against the bottom of a litter during storage or while the litter is loaded. The plate(s) could be held in the storage position by a latch that could be released manually or automatically as the litter is hoisted. Upon release, springs would move the plates into the deployed position.

This work was done by John Wilson of **Langley Research Center.** *No further documentation is available.*
LAR-14558



Vertical Plates on the Underside would provide aerodynamic stabilization against spinning of a litter during hoisting into a helicopter.

Improved Spline Coupling for Robotic Docking

The mating surfaces are redesigned to reduce stresses.

Goddard Space Flight Center, Greenbelt, Maryland

Figure 1 shows a robotic docking mechanism like the one described in "Self-Aligning Mechanical and Electrical Coupling" (GSC-13430), NASA Tech Briefs, Vol. 17, No. 3 (March 1993), page 92. Figure 2 shows part of the mechanisms and includes an enlarged view of the spline coupling that is part of the mechanism. The spline coupling has been redesigned to reduce stresses, thereby enhancing the performance and safety of the mechanism. The redesign does not involve a significant increase in size.

At the beginning of a docking sequence, the two bodies to be joined are brought into coarse alignment, then become aligned more finely as the wheels mate with the V-grooves and the chambered surfaces on the two bodies come into contact. During this approach, the spline driver is rotated in the upper body until its splines fall through the spaces between the splines in a receptacle at the top of a driven bolt in the lower body. The approach ends in a soft-docking phase in which an alignment cone on the driver mates with a conical alignment hole in the receptacle.

The driven bolt is right-hand threaded into a captive nut that is restrained against rotation but is free to translate vertically between hard stops. The bolt is also spring-loaded downward in the lower body. Following soft-docking, the spline driver is rotated clockwise until its tightening tabs make contact with the torque tabs in the receptacle, and the receptacle (and, therefore, the bolt) begins to rotate clockwise with the spline driver. This motion causes the receptacle to move downward until the convex spherical load-bearing surfaces on the spline driver make contact with mating spherical load-bearing surfaces in the receptacle, and these surfaces begin to bear the spring load.

Further clockwise rotation causes the captive nut to move upward, the dust covers are opened, and male electrical connectors mounted on the nut mate with female electrical connectors mounted in the upper body. When the captive nut reaches the upper limit of its motion, the full tensile docking preload between the upper and lower bodies is assumed by the mating spherical surfaces. The use of spherical mating surfaces (in comparison with the mating surfaces of the prior design) results in larger shear-plane lengths and areas and, consequently, in lower stresses. Furthermore, the spherical shape tolerates slight misalignments without drastic redistribution of the main tensile preload.

At the beginning of an undocking sequence, the spline driver is rotated counterclockwise, and the releasing tabs push against the torque tabs so that the driven bolt must also rotate counterclockwise. As the captive nut reaches the lower limit of its travel and rotation continues, the driven bolt begins to move upward. This motion continues until the torque tabs rise out of the way of the releasing tabs. Then the driver can be rotated into a position in which it can be pulled out of the receptacle, and the two bodies can be pulled apart.

This was work done by John M. Vranish of **Goddard Space Flight**

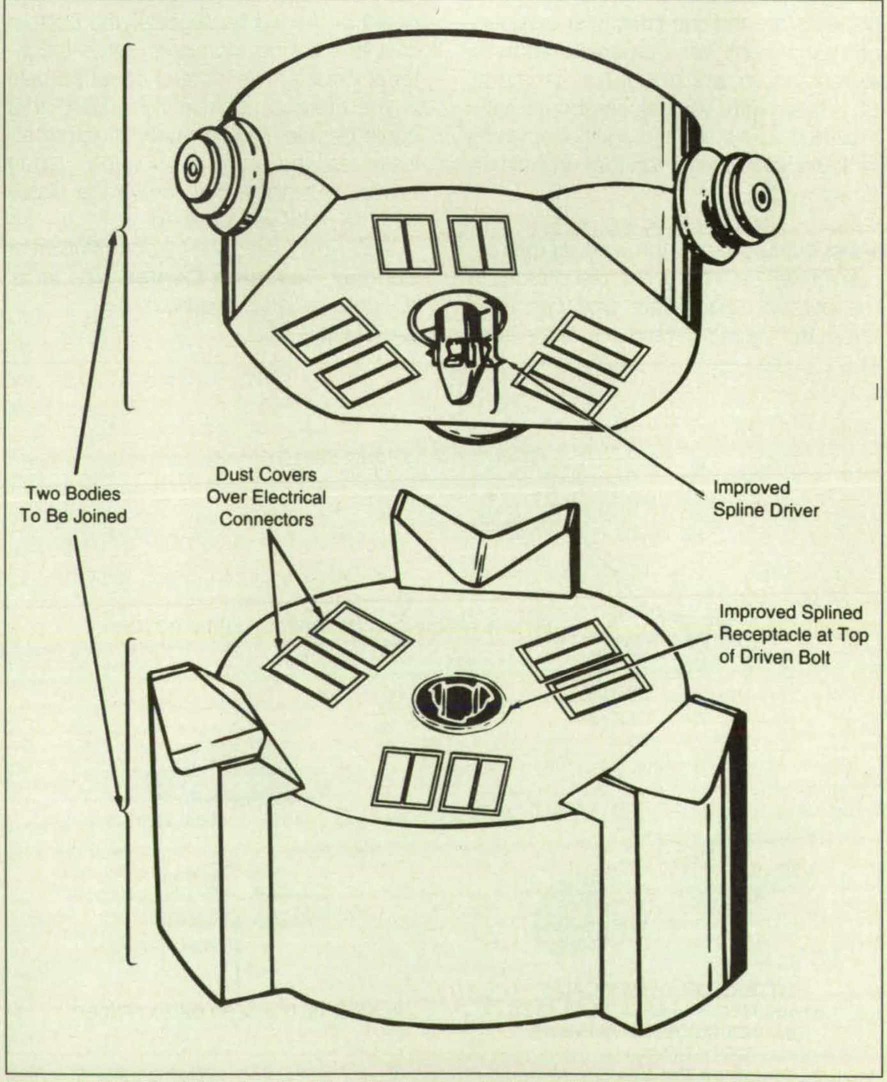


Figure 1. This Self-Aligning Docking Mechanism includes the improved spline coupling.

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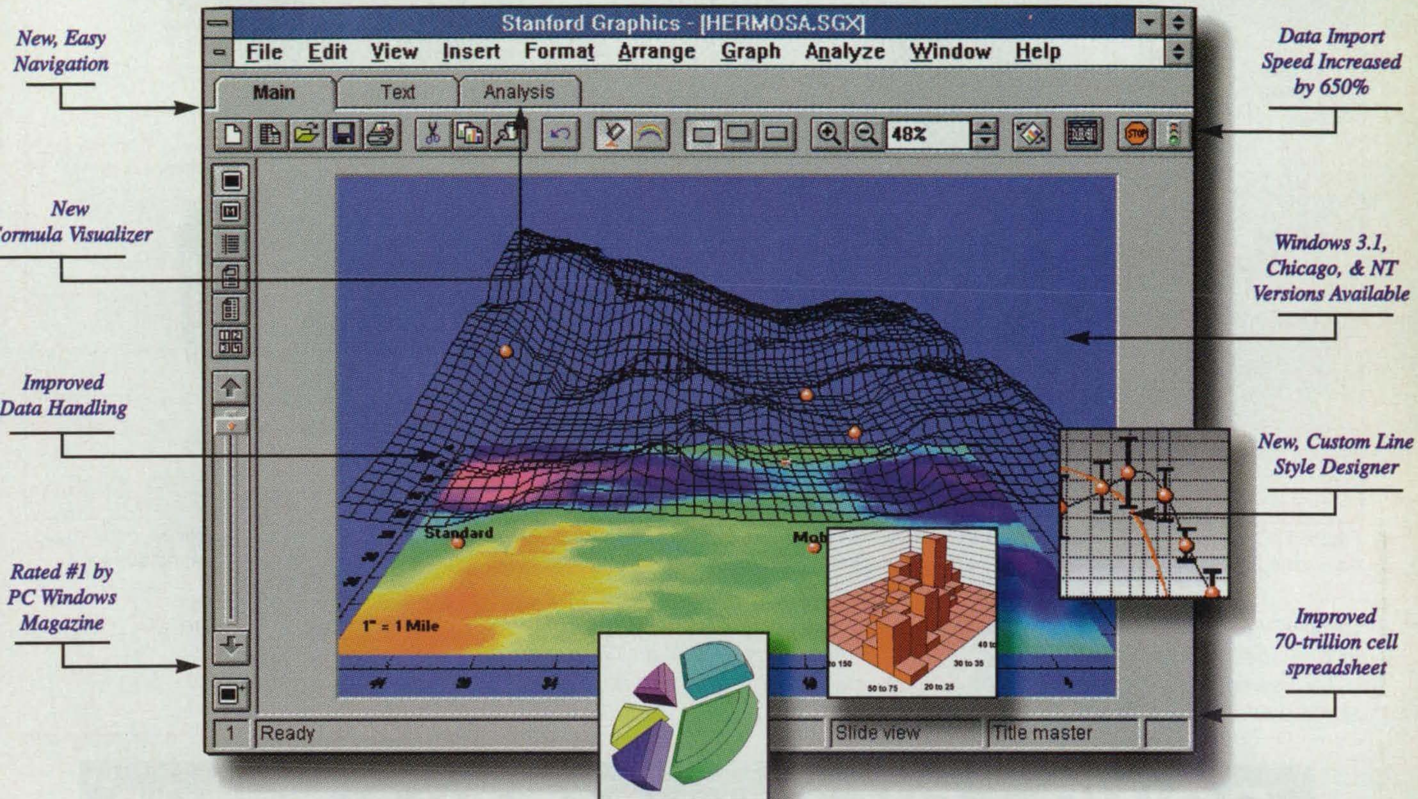

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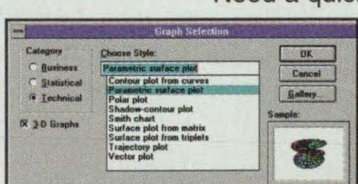

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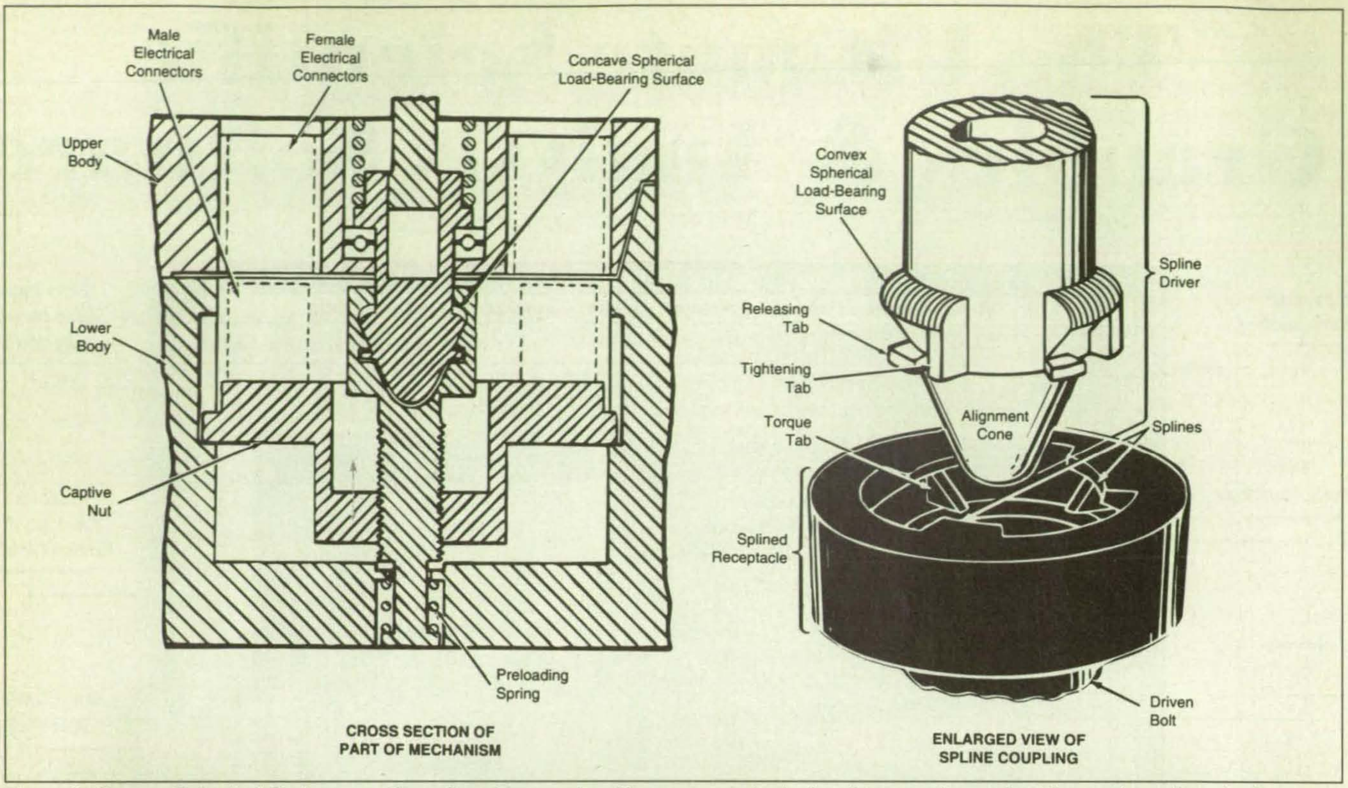

Figure 2. Convex Spherical Surfaces on the spline driver mate with concave spherical surfaces on the undersides on the splines in the receptacle. The spherical surfaces distribute load stresses better and tolerate misalignments better than do flat and otherwise shaped surfaces.

Center. *For further information,* ***write in 6*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center [see page 20]. Refer to GSC-13434.

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Process Makes Thermoplastic Prepreg Ribbon

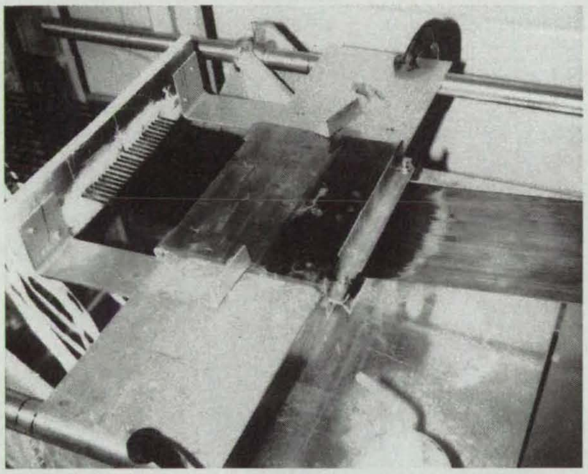
Any of a variety of fibers and thermoplastic resins can be used.

Langley Research Center, Hampton, Virginia

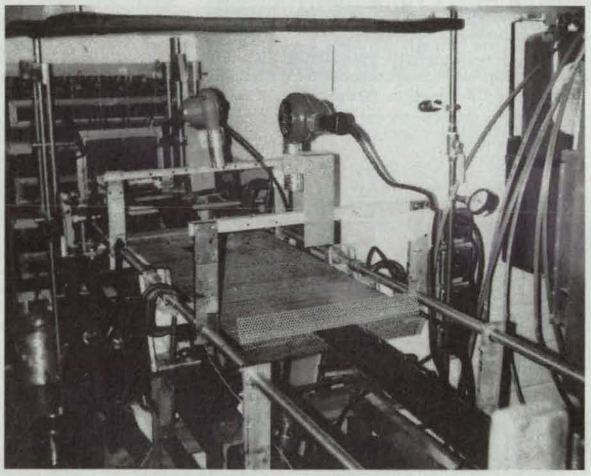
A manufacturing process produces a ribbon of composite material (prepreg) that consists of continuous lengthwise fibers impregnated with thermoplastic resin. The ribbon can later be cut into sheets of the required sizes and shapes, stacked, then heated under pressure to form composite-material structural components. The present manufacturing process accommodates a variety of thermoplastic resins and a variety of fibers (e.g., graphite, glass, or polymeric fibers). This process eliminates the need for older processes in which fiber tows are coated individually, then wound or laid together: these older processes are time-consuming, and the quality of the resulting prepregs is generally poor.

The process is carried out in a modified version of a commercial pultrusion machine (see figure). Tows of graphite or other fiber are fed to the process from many spools on a creel. The tows are aligned parallel and spaced about 0.25 in. (6.35 mm) apart. They are pulled (by reciprocating pullers at the far end) through an impregnation tank. The tank can be filled with a slurry of resin in liquid or with resin fully dissolved in a solvent. In the case of a slurry, the liquid can be a mixture, the proportions of the ingredients of which are selected so that the specific gravity of the liquid matches that of the resin particles. This helps to ensure that the particles remain in a uniform suspension.

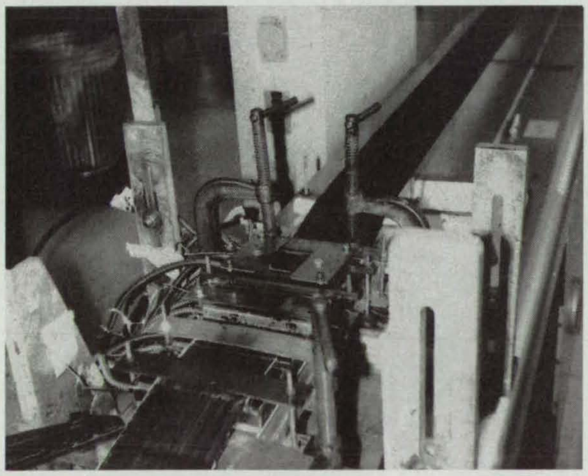
In the tank, each tow is spread to a width of 0.375 in. (about 9.5 mm) and is forced under round bars so that it follows the contour of the bottom of the tank, which is corrugated. This action ensures that the resin fully impregnates the fiber



IMPREGNATION TANK WITH TOP IN PLACE



FORCED-AIR-DRYING SECTION



HEATED DIES

FINISHED PREPREG RIBBON BEING WOUND ONTO TAKEUP SPOOL

Fiber Tows Are Spread and impregnated with resin from a slurry or solution, then dried and then heated and pressed to form a prepreg ribbon.

tows. At the exit end of the tank, the tows pass through a metering die, the openings of which are sized to allow no more than a predetermined amount of resin suspension or solution to leave with the tows. The die thus fixes the resin-to-fiber ratio.

The resin-impregnated tows next pass between a pair of perforated plates, where flowing hot air evaporates about 90 percent of the solvent or suspension liquid. The tows then pass over a final set of heated dies, which remove the remaining liquid and spread and compact the tows and resin to form the ribbon to the desired thickness. The ribbon is then coiled on a takeup spool.

This work was done by Maywood L. Wilson and Gary S. Johnson of **Langley Research Center.** *For further information,* ***write in 287*** *on the TSP Request Card.*

This invention has been patented by NASA (U.S. Patent No. 5,205,898). Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14459

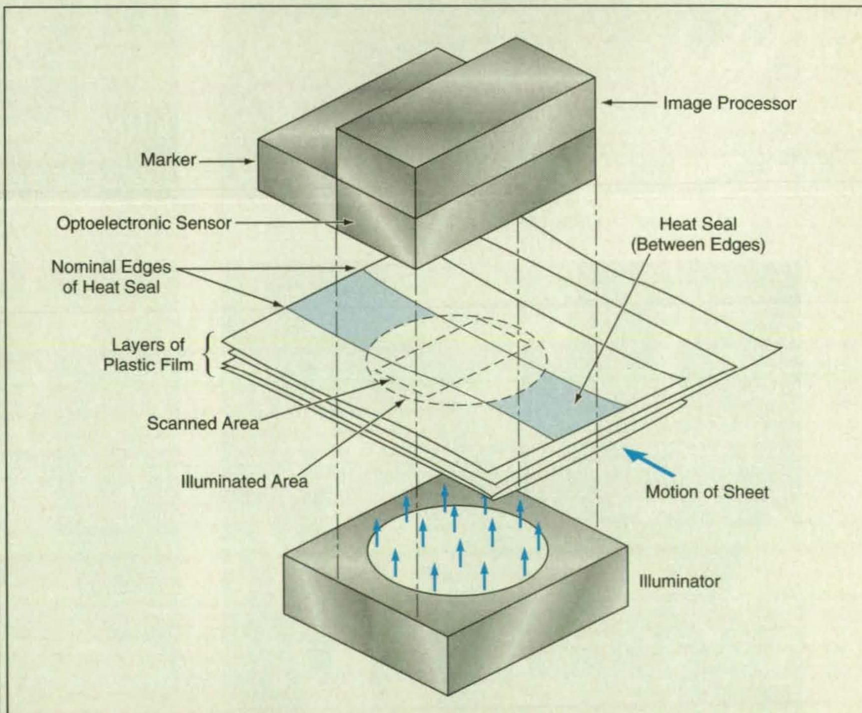
Automatic Inspection of Heat Seals Between Plastic Sheets

An inspection apparatus analyzes light passing through seal strips.

Goddard Space Flight Center, Greenbelt, Maryland

An automatic inspection apparatus detects flaws in heat seals between films of polyethylene or other thermoplastic material. Heat sealing is used to join plastic films in the manufacturing of a variety of products, including inflatable toys and balloons that carry scientific instruments to high altitudes. In heat sealing, multiple layers of film are heated and pressed together along a strip. Flaws are introduced by variations in the temperature, pressure, and speed of the bonding process, by wrinkles and twists in the films, and by trapping of foreign materials between layers. Because flaws weaken the bond, it is necessary to inspect the seal to ensure adequate strength. The automatic inspection apparatus can identify and mark flaws at production speed, making it possible to subsequently allocate the limited resources for slower and more thorough manual inspection and repair to only those spots that have been marked.

The inspection apparatus detects flaws optoelectronically (see figure). The



The **Heat-Sealed Strip** in the multilayer plastic sheet is continuously moved lengthwise over the illuminators. The variations in light transmitted through the sheet are interpreted to find flaws in the heat seal. The site of a flaw is marked to facilitate subsequent manual inspection.

heat-sealed sheet is moved continuously through the apparatus, along the heat seal, positioned laterally so that the heat seal rides above an illuminator. A beam of light from the illuminator passes through the sheet. Above the sheet, a linear array of photodetectors lies in a narrow scanning area that crosses the nominal heat-seal strip. This array measures the distribution, along a line that crosses the seal, of light transmitted through the seal and a small adjacent width of the sheet.

The outputs of the photodetectors are fed to an image processor, which identifies edges of sealed areas in terms of sharp dark-to-light and light-to-dark transitions. A good seal should not be clouded, should not contain darkening or brightening foreign particles or bubbles, and should be bonded by only two edges at the specified lateral positions. As such, it should be characterized by a distribution of transmitted light that conforms to a standard developed from measurements on seals that have been inspected manually and are known to be good.

The image processor executes an algorithm that identifies defects by analyzing the distribution of light and identifying significant deviations from the standard. Specifically, insufficient distance between the two nominal edges indicates that the seal was not heated enough and could, therefore, be weak. Other defects are indicated by the presence of more than two significant edges. In each case, the apparatus marks the sheet at the site of the flaw.

This work was done by Kula R. Rai, Thomas M. Lew, and Robert B. Sinclair of Winzen International, Inc., for **Goddard Space Flight Center.** *For further information,* ***write in 7*** *on the TSP Request Card.*
GSC-13410

Net-Shape Tailored Fabrics for Complex Composite Structures

Components of looms include custom reed and differential fabric takeup system.

Langley Research Center, Hampton, Virginia

Proposed novel looms would be used to make fabric preforms for complex structural elements, both stiffening elements and skin, from continuous fiber-reinforced composite material (fiber and matrix). The structural parts that can be made using this technology are best explained by reference to a curved "I" cross-section frame (see Figure 1).

The frame can be constructed from an assembly of back-to-back C channels with upper and lower caps. Each C channel consists of nested layers of fabric. The fiber orientations in the web of the single layer fabric that comprises the C channels is at + or − 45° relative to the longitudinal axis of the frame. The flanges of the C channel could also be at the same angle or changed to some other angle, e.g., 90°. The caps would contain a high percentage of fibers oriented parallel (at 0°) to the longitudinal axis of the frame with some fibers at 90° and 45°. This technology is not limited to these fiber orientations or this geometry; that is, the fiber angles, frame radius of curvature, frame height, and flange width can all be changed along the length of the structure.

The aforementioned single layer fabric cannot be readily fabricated using current weaving technology. Before such parts can be woven, three technical issues must be addressed: (1) How to weave the fill yarns at angles other than perpendicular to the warp yarns, (2) how to change the width of the part along its length, and (3) how to create curvature in the fabric.

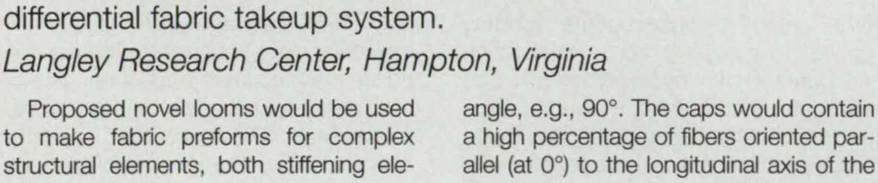


Figure 1. A **Curved Composite-Material I-Beam** would be fabricated by assembling C channel and flat cap fabric preforms impregnated with epoxy or other matrix material, then curing the matrix material.

The first and second issues are addressed by the loom reed. The fill yarn conforms to the profile of the reed (see Figure 2). Therefore, by changing the profile of the reed relative to the warp yarns in the fabric, any desired fill yarn fiber angle can be achieved. The width of the fabric coincides with the location of the warp yarns, which is controlled by the reed. By using a fan-type reed it is possible to change the location of the warp yarns and hence the fabric width along the length of the fabric. The third issue is associated with the take-up system of the loom. To create curvature in the fabric, a differential fabric takeup system is used. This system can be a modification of the conical rollers used in producing spiral fabric; an alternative is the use of a clamping bar takeup system.

This weaving technology is equally applicable to structural skins, such as wing or fuselage skins. The fabric fiber orientations can be tailored across and along the length of the structure in forming the net-shape structural preform.

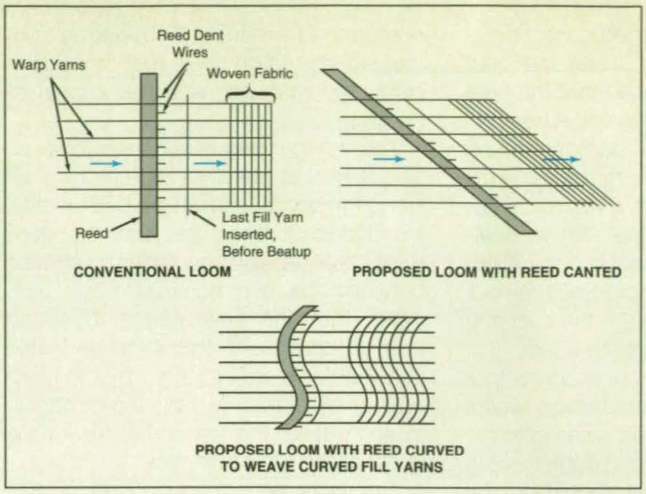


Figure 2. **Weaving a C Channel** with fill yarns in the desired configuration and with a curved web would be accomplished by several novel features that would be incorporated into the proposed loom.

This work was done by Gary L. Farley of the U.S. Army Vehicle Structures Directorate at the **Langley Research Center.** *No further documentation is available.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-14752.

Safety-Enclosure System for MOCVD Process Chamber

Toxic byproducts of the MOCVD process are collected within an inert atmosphere.

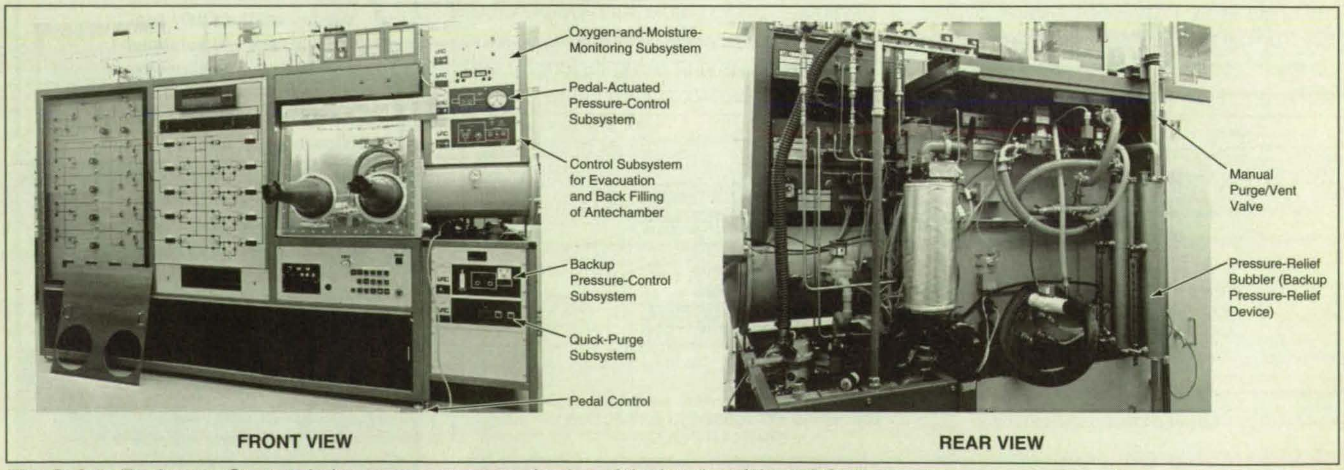
NASA's Jet Propulsion Laboratory, Pasadena, California

A safety-enclosure system filled with nitrogen surrounds a reaction chamber in which metallo-organic chemical vapor deposition (MOCVD) is performed. The safety enclosure (see figure) is designed to protect against explosions and/or escaping toxic gases and particulates. A gas-purification subsystem of the safety enclosure ensures that during loading and unloading of process materials, the interior of the MOCVD chamber is exposed to less than 1 ppm of oxygen and less than 5 ppm of water in the nitrogen atmosphere.

The safety-enclosure part of the system is a hermetically sealed, 16-gauge [about 0.06-in. (1.5-mm) thick] stainless-steel glove box with a shatter-resistant Lexan™ polycarbonate window coated to protect it from deterioration via contact with hydrocarbon oil. Left and right 30-mil (0.8-mm) butyl-rubber gloves are attached to two glove ports embedded in the polycarbonate window. The safety-enclosure system includes subsystems that maintain the purity and regulate the pressure of the nitrogen atmosphere.

The dangerous components from the MOCVD reaction chamber that accumulate in the enclosed nitrogen atmosphere are removed by filtering the particles and condensing the volatile components in a liquid-nitrogen-cooled trap. Probes in the enclosure warn of residual toxic gases. Residual oxygen and water are removed by an oxygen-getter-and-molecular-sieve subsystem. To keep the nitrogen atmosphere cool, a refrigerator unit removes heat added by the operation of the MOCVD chamber. The enclosure is strong enough to contain any fragments in the unlikely event of an explosion (which could be caused by ignition of hydrogen leaking from the MOCVD chamber).

This work was done by James Singletery, Jr., and Hugo Velasquez of Caltech for **NASA's Jet Propulsion Laboratory** *and Joseph Warner of Lewis Research Center. For further information,* ***write in 117*** *on the TSP Request Card.*
NPO-18872



The **Safety Enclosure System** helps to prevent contamination of the interior of the MOCVD chamber and protects workers against toxic emissions from the chamber.

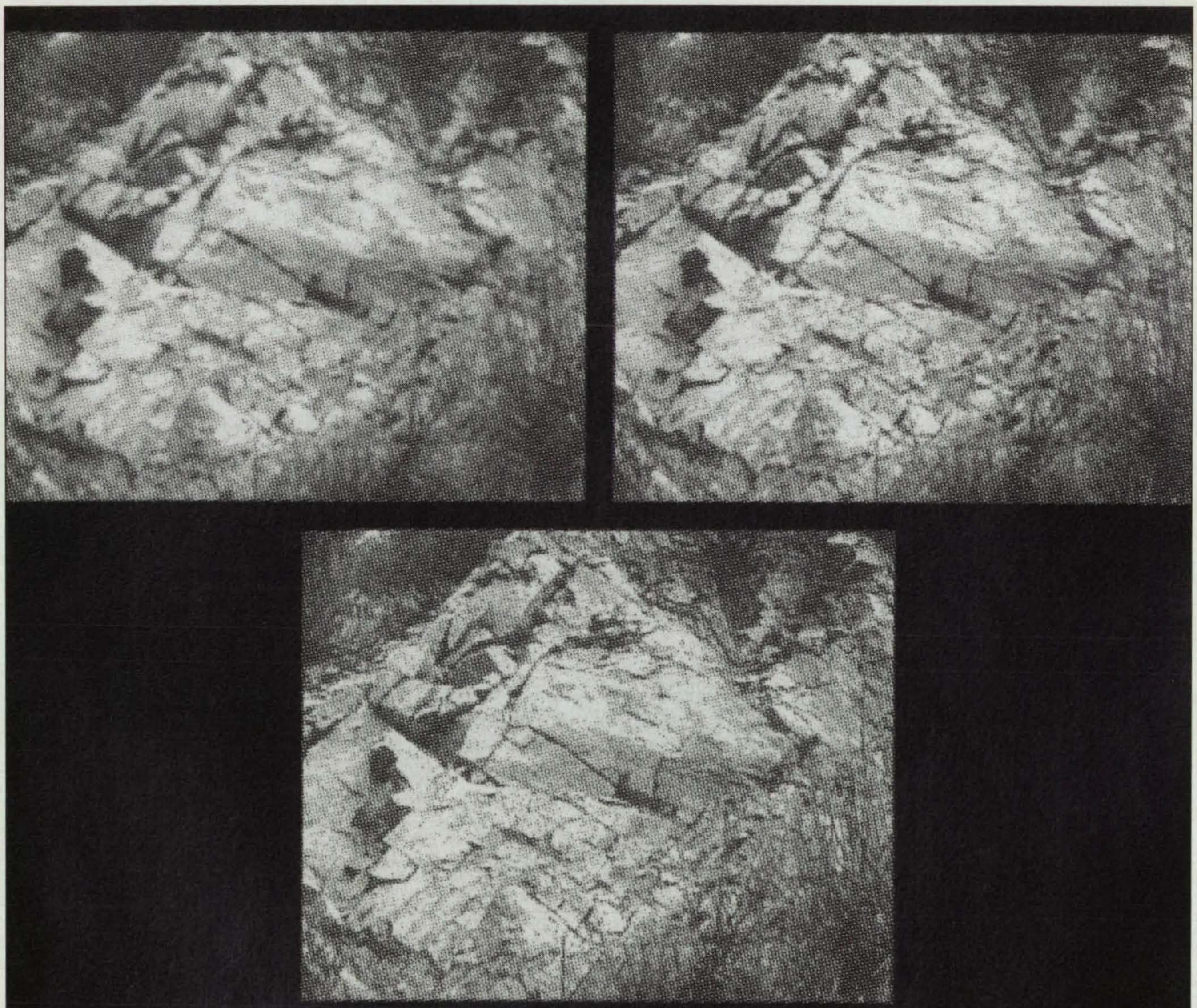
Enhancing Images by Nonlinear Extrapolation in Frequency

This method is suitable for real-time applications.

NASA's Jet Propulsion Laboratory, Pasadena, California

An improved method of enhancing the edges in an image involves a nonlinear filter operation that creates image-intensity components that have spatial frequencies higher than those present in the input image and that are locked in phase to the lower-frequency input components. In comparison with other edge-enhancement methods that involve mostly the strengthening of higher-frequency components already present in the input, this method is computationally simpler and yields better results. Consequently, this method should be better suited to real-time applications like high-definition television and compression of image data.

The nonlinear filter operation of the improved method is based on two theoretical concepts that have emerge in recent years: the pyramidal representation of an image, and the scale-space formalism as applied to the representation of edges. The pyramidal representation involves what are called "Gaussian pyramids" and "Laplacian pyramids:" The Gaussian pyramid consists of low-pass-



A **Blurred Image of a Rock Scene** is presented top left. Augmenting the high-frequency components present in the given image results in an enhanced image, as shown top right. As shown in the bottom part of the figure, the blurred input is enhanced by use of a nonlinear filtering process that generates additional high-spatial-frequency components, thus making the edges more visible.

filtered (LPF) versions of the input image, with each stage of the pyramid achieved by Gaussian filtering of the previous stage and corresponding sub-sampling of the filtered output. The Laplacian pyramid consists of band-pass-filtered (BPF) versions of the input image, with each stage of the pyramid constructed by the subtraction of two corresponding adjacent levels of the Gaussian pyramid. The Laplacian pyramid can also be viewed as a difference-of-Gaussians (DOG) pyramid, wherein the DOG kernel, which is a good approximation to the Laplacian operator, is convolved with the input to produce corresponding edge maps. Thus, the Laplacian-pyramid representation includes the edge maps of the input at different resolutions. The Laplacian pyramid is a special case of the wavelet representation; as such, it preserves the shapes and phases of the edge maps at different scales. Edges are thus represented similarly at all scales.

It has been shown that the Laplacian pyramid forms a complete representation of the image, enabling full reconstruction of the image. Let the input image be denoted as G_0, let the LPF versions of the input image be denoted as G_1 through G_N in order of decreasing resolution, and let the corresponding edge maps or band-pass images be denoted as L_0 through L_N, respectively. Then the reconstruction process involves the addition of a BPF version of the image, L_k ($N \geq k \geq 0$) to the corresponding LPF version of the image, G_{k+1} to obtain the next level of the Gaussian pyramid, G_k. Thus, the levels of the pyramid are constructed by the recursive process $G_k = L_k + G_{k+1}$, leading to reconstruction of the original image, G_0.

The pyramidal representation can be viewed as a discrete version of the scale-space formalism, in which the position of an edge (defined as the position of the zero crossing of the second derivative of the image brightness) is given across a continuum of scales. The improved method exploits the shape-invariant properties of edges across scale in the pyramidal representation and in agreement with the consistency characteristic of the scale-space formalism. The enhanced image that one seeks to generate in this method can be represented via a pyramidal extrapolation, namely $G_{-1} = L_{-1} + G_0$. A suitable nonlinear operation to generate the L_{-1} component from the L_0 component could involve thresholding followed by multiplication followed by bounding, all implemented by use of the digital electronic equivalent of that lookup table. The figure illustrates the enhancement of an image of rocks by use of this method.

This work was done by Charles H. Anderson and Hayit K. Greenspan of Caltech for **NASA's Jet Propulsion Laboratory**. *For further information,* ***write in 201*** *on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

William T. Callaghan, Manager
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JPL-301-350
4800 Oak Grove Drive
Pasadena, CA 91109

Refer to NPO-18943, volume and number of this NASA Tech Briefs *issue, and the page number.*

Reduction of Sizes of Semi-Markov Reliability Models

A trimming technique reduces computational effort by an order of magnitude while introducing negligible error

Langley Research Center, Hampton, Virginia

Semi-Markov processes have proved to be both effective and convenient for constructing mathematical models of systems that are made reliable by use of redundancy and the capability of reconfiguration. These models can depict complicated systems and capture (via simulation) the essential features of the dynamics of the arrival of faults and the recovery of systems from faults. One disadvantage is that the models can be extremely large, posing problems both of construction and of computation. Sound and effective procedures to reduce the sizes of the models ("model-reduction methods" for short) are needed.

Because the systems represented by the models are used in critical applications, an acceptable model-reduction method must provide for an analytically derived error bound. A model-reduction method must be easy to implement, and the error bound easy to compute. A model-reduction method called "trimming" can be applied to a popular class of systems, and an error bound for this method depends on readily available parameters of the modeled system.

The error bound depends on only three parameters from the semi-Markov model: the maximum sum of rates for failure transitions leaving any state, the maximum average holding time for a recovery-mode state, and the operating time for the system. The error bound can be computed before any model is generated, enabling the modeler to decide immediately whether or not the model can be trimmed. The trimming procedure is specified by a precise and easy description, which makes it easy to include the trimming procedure in a program that generates mathematical models for use in assessing reliability.

Two models, complete and trimmed, were constructed for a sample system by use of the ASSIST reliability-model-generating computer program. The complete model contained 227 states and took 7,878 seconds to compute. The trimmed model contained 83 states and took 258 seconds to compute. The relative error produced by model trimming was approximately 1 part in 10 million, while the error bound for model trimming was approximately 1 part in a thousand. The results from this example are typical for an application of trimming. The number of states in the reliability model was reduced by about half. The computational effort was reduced by an order of magnitude. The actual error from trimming was insignificant. The derived error bound for trimming was much larger than the actual error, but still small in comparison with the computed probability of failure of the system.

A typical application of this technique is in the design of digital control systems that are required to be extremely reliable. An example is the proposed requirement that the probability of failure of the flight-control system of a commercial aircraft during a 10-hour flight be less than 1 billionth. In addition to aerospace applications, fault-tolerant design has growing importance in a wide range of industrial applications. Simple, intuitive analytic methods like this one should help strengthen industrial practice.

This work was done by Allan L. White and Dan L. Palumbo of **Langley Research Center** *Further information may be found in NASA TP-3089 [N91-25741], "Model Reduction by Trimming for a Class of Semi-Markov Reliability Models and the Corresponding Error Bound."*

Copies may be purchased [prepayment required] from the NASA Center for AeroSpace Information, Linthicum Heights, Maryland, Telephone No. (301) 621-0390. Rush orders may be placed for an extra fee by calling (800) 336-4700. LAR-14363

Life Sciences

Beat-Frequency/Microsphere Medical Ultrasonic Imaging

Microspheres used as contrast enhancers can be detected in low concentrations.

Langley Research Center, Hampton, Virginia

A medical ultrasonic imaging system is designed to provide quantitative data on the various flows of blood in the chambers, blood vessels, muscles, and tissues of the heart. The system detects microspheres that have been placed in the blood to enhance ultrasonic contrast. Older ultrasonic systems constructed for the same purpose are relatively insensitive; they can extract useful data only when large concentrations of microspheres are created in the immediate vicinity of the heart via catheterization or surgery. The present system offers greater sensitivity; it can extract useful data at the lower concentrations of microspheres that are produced by ordinary injection into the bloodstream at a site remote from the heart.

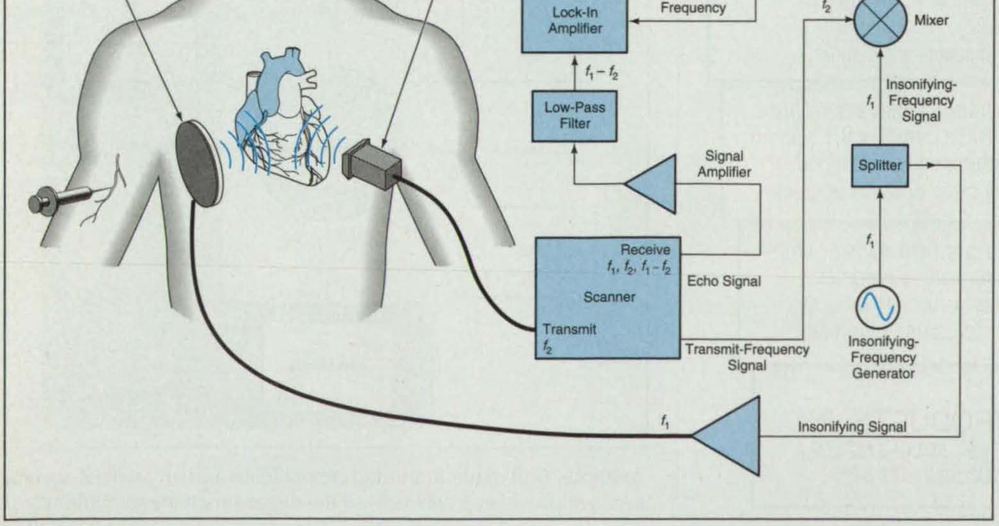
The system (see figure) includes two ultrasonic transducers: the insonifying transducer and the scanning transducer. The insonifying signal is a continuous wave at a single, precise radio frequency (typically, 5.2 MHz). The insonifying signal originates in a signal generator, is amplified by a radio-frequency power amplifier, and is then fed to the insonifying transducer, which couples ultrasonic energy at the radio frequency into a patient's chest.

The scanning transducer also couples ultrasonic energy into the patient's chest, at a single frequency, but the scanning frequency (typically, 5.0 MHz) differs from the insonifying frequency. In addition, the scanning transducer receives ultrasonic echoes and sends the echo signals to the signal-processing electronic equipment for processing into a video image. The person conducting the examination moves the scanning transducer while observing the image to find the heart region of interest.

The signal-processing equipment includes a mixer, a summer, two low-pass filters, a signal amplifier, and a lock-in amplifier. A computer controls the operation of the system, plots concentrations of microspheres as functions of time, and derives such blood-flow parameters as time to the peak of a flow curve, time to half peak on ascending and descending portions of the curve, half-time slopes of the curve, time of appearance of microspheres, and area under the curve.

The myocardial tissue responds linearly to the incident ultrasound; it returns ultrasonic echoes at the insonifying and scanning frequencies only. On the other hand, the microspheres respond partly nonlinearly to the incident ultrasound and thus act as ultrasonic mixers; they reradiate ultrasound not only at the insonifying and scanning frequencies but also at the sum and difference of these frequencies (beat frequencies). Thus, ultrasonic echoes from blood that contains microspheres can be distinguished from other echoes by their beat-frequency content.

The ultrasonic echo signals are fed from the scanning transducer to a signal amplifier, then to one of the low-pass filters, which passes only the difference frequency (e.g., 0.2 MHz) plus the low-frequency component of noise. The output of the low-pass filter is fed to a lock-



This **Beat-Frequency/Microsphere Ultrasonic Imaging System** is sensitive enough to yield readings on flows of blood in the heart even when the microspheres used as ultrasonic contrast agents are injected far from the heart and are diluted by circulation of blood elsewhere in the body.

in amplifier — a high-gain, extremely-narrow-band amplifier that detects only signals of precisely the difference frequency by mixing the signal transmitted through the low-pass filter with a reference difference-frequency signal. This reference signal is generated by mixing the signals from the insonifying- and scanning-frequency generators and processing the output of the mixer through the other low-pass filter.

This work was done by William T. Yost and John H. Cantrell of **Langley Research Center** *and Robert A. Pretlow III of Lockheed Engineering and Sciences Corp. No further documentation is available.*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Langley Research Center [see page 20]. Refer to LAR-15211.

Artificial Soil With Built-in Plant Nutrients

Nutrients are contained in a sandlike material.

Lyndon B. Johnson Space Center, Houston, Texas

An artificial soil provides nutrients to plants during several growing seasons without need to add fertilizer or a nutrient solution. When watered, the artificial soil slowly releases all the materials a plant needs to grow. The artificial soil was developed as a medium for growing crops in space. It could also be used to grow plants on Earth under controlled conditions or even to augment natural soil.

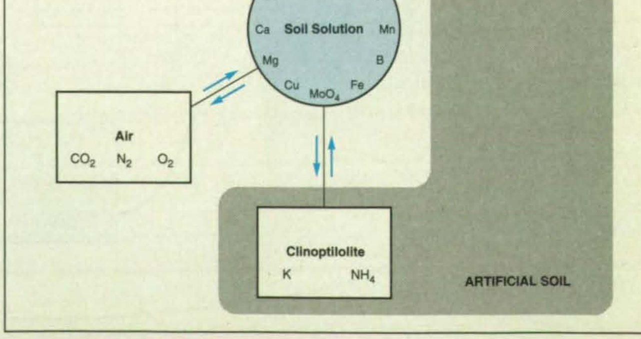
The artificial soil consists of several major components and their subcomponents, each of which plays a distinct and essential role in supplying nutrients. One of the major components is clinoptilolite, which is a natural mineral that exhibits a high capacity for exchange of cations. Two types of nutrient-saturated clinoptilolite are incorporated into the soil. The preparation of both begins with packing of particles of clinoptilolite into a column. In one case, a KCl solution is passed through the column; in the other case, an NH_4Cl solution is passed through the column. Then deionized water is passed through the column to remove excess residual KCl or NH_4Cl.

The exchange sites of the clinoptilolites thus treated are saturated with K and NH_4 ions, respectively. The clinoptilolite component of the artificial soil is made by mixing 3 parts of ammonium-saturated clinoptilolite with 1 part of potassium-saturated clinoptilolite. This mixture supplies the potassium and the nitrogen (contained within the ammonium ions) needed by growing plants. The clinoptilolite mixture is incorporated into the artificial soil in the proportion of 5 to 10 parts by weight (out of a total of 6 to 14 parts).

Another major component of the artificial soil is a synthetic apatite fertilizer that is free of fluorine, cadmium, lead, and other toxic elements that occur in natural apatite. The artificial apatite features a calcium phosphate matrix into which the desired nutrients can be dispersed by suitable chemical processing. This component of the soil slowly supplies calcium, phosphorus, magnesium, sulfur, iron, manganese, copper, molybdenum, boron, chlorine, and zinc. It is incorporated into the artificial soil in the proportion of 1 or 2 parts by weight. The soil has a sandlike consistency.

This work was done by Douglas W. Ming, Earl Allen, and Donald Henninger of **Johnson Space Center** *and D. C. Golden of the National Research Council. For further information,* ***write in 8*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Johnson Space Center [see page 20]. Refer to MSC-21954.



Artificial Soil made of treated clinoptilolite and an artificial-apatite fertilizer provides plants with all the necessary mineral nutrients.

Books & Reports

These reports, studies, and handbooks are available from NASA as Technical Support Packages (TSPs) when a Request Card number is cited; otherwise they are available from the NASA Center for Aerospace Information.

Machinery

More About Hazard-Response Robot for Combustible Atmospheres

A report presents additional information about the design and capabilities of the mobile hazard-response robot called "Hazbot III." This robot was depicted on the cover of NASA Tech Briefs, Vol. 17, No. 10 (October 1993) and described in a feature article on pages 16 and 17 of that issue. Hazbot III is designed to operate safely in a combustible and/or toxic atmosphere. It includes cameras and chemical sensors that help human technicians determine the location and nature of a hazard so that a human emergency team can decide how to eliminate the hazard without approaching it themselves.

This work was done by Henry W. Stone and Timothy R. Ohm of Caltech for **NASA's Jet Propulsion Laboratory**. *To obtain a copy of the report, "An Emergency Response Robot for Operations in Combustible Atmospheres,"* ***write in 123*** *on the TSP Request Card.*

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, NASA Resident Office–JPL [see page 20]. Refer to NPO-19020.

Physical Science

Shades Would Keep Infrared Telescope Cold

A report proposes the use of multiple shades to prevent solar heating of an infrared telescope in high orbit around the Earth. The shades would be part of a lightweight stowable structure that would be deployed by inflating it. The shades would be oriented so as not to interfere with the field of view of the telescope. In conjunction with a telescope design that provides for passive self-cooling by radiation to outer space in directions away from the sun, a multilayer shade design with provision for similar radiative cooling should enable the telescope to reach a low temperature in the range of 10 to 30 K.

This work was done by Donald Rapp of Caltech for **NASA's Jet Propulsion Laboratory.** *To obtain a copy of the report, "Passive Cooling Technique for IR Observatories,"* ***write in 206*** *on the TSP Request Card.*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to

William T. Callaghan, Manager
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JPL-301-350
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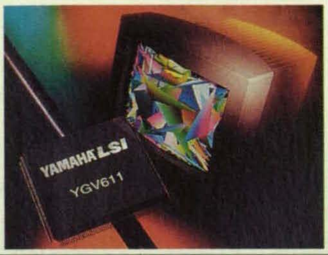
Refer to NPO-19076, volume and number of this NASA Tech Briefs issue, and the page number.

New on the Market

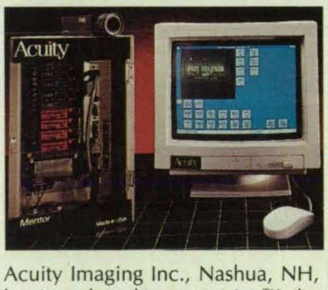
Yamaha Systems Technology Division, San Jose, CA, is offering the Rendering Polygon Accelerator (RPA), a new "virtuality" **3D graphics chip** for PCs or low end workstations designed to enhance animation, presentations, modeling, CAD/CAM, and virtual reality applications. It performs Gouraud shading and texture mapping at 210K polygons/sec. (50-pixel polygons), hidden surface removal, and bit block transfer. The frame buffer interface is 128 bits wide (64-bit interleaved), and the 16- or 32-bit-wide host bus interface operates up to 33 MHz.

For More Information Write In No. 704



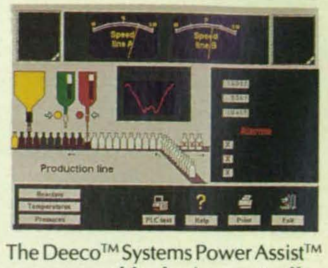
The compact C-001 **vacuum casting machine** unveiled by MCP Systems Inc., Fairfield, CT, provides enough working space to handle most prototype electronic components. A bench-mounted system with easy-to-operate controls for mixing, casting, and air evaluation, the C-001 has two vacuum chambers--one for mixing the resin and the other for casting the resin into the mold. Mixing and casting take place in a vacuum up to 7.5×10^{-4} Torr to ensure air is not trapped either in mold or resin.

For More Information Write In No. 709



Acuity Imaging Inc., Nashua, NH, has introduced Mentorvision™, the first **automated inspection system** to use the company's Intelligent Vision technology. Designed for high-volume, multi-line manufacturing operations placing high value on the product's external appearance, the system can recognize a wide variety of packaging defects including drips, wrinkles, dirt, or wrong labels. The virtually self-programming, neural-network-based system uses a show-and-go approach to learn a product by viewing 100-200 good and bad examples.

For More Information Write In No. 712



The Deeco™ Systems Power Assist™ **programmable logic controller graphic user interface software** from Lucas Control Systems Products, Hayward, CA, can run in either a single control system environment or a network where data exchange is critical. The PC-based program can import drawings from any Windows-based graphic program and files from most Autocad systems to create and animate trend lines, graphs, value displays, messages, set points, and color fills on the same screen. It also supports logic and math calculations, uploads and downloads recipe files, and saves data to disk.

For More Information Write In No. 707

New **integrated linear motion guide actuators** from THK America Inc., Schaumburg, IL, combine the ball screw and linear motion guide inside a single-piece, drawn-steel outer rail system. The KR33 has a cross-section of 33 x 60 mm and a dynamic load rating of 536 lb on the load-block, while the KR46 has a cross-section of 16 x 86 mm and a load rating of 1273 lb on the load-block. Both models can help solve the problem of increasing load capacity while reducing package size.

For More Information Write In No. 701

BioComp Systems Inc., Redmond, WA, has introduced the NeuroGenetic Optimizer (NGO™) for Windows™, a **neural network organization tool** that helps developers find the best combination of input variables and neural network structures to maximize network accuracy while minimizing size. The NGO enables the user to load and view data, set neural and genetic algorithm parameters, observe the evolving population of input variables, and log to disk descriptions of the best inputs/networks as they are discovered.

For More Information Write In No. 705

New on the Market

Pressurex®, a **tactile pressure detecting film** introduced by Sensor Products Inc., East Hanover, NJ, indicates compression magnitude and distribution between contact surfaces by turning a shade of red that varies according to the stress applied. With an 8-mm cross-section, the film can operate in many invasion-intolerant environments and comes in five sensitivities for pressure detection from 28 lb/in^2 to 18,500 lb/in^2.

For More Information Write In No. 713

A **programmable motion controller** for PCs from Animatics, Santa Clara, CA, integrates a brushless DC servo motor, encoder, controller, and amplifier in one compact package. Just 1.25 inches longer than a standard 23 size motor, SmartMotor™ operates over RS-232 either by itself or in a chain. All commands are sent as ASCII strings.

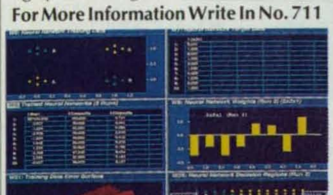
For More Information Write In No. 710

Conference Link, a **workstation conferencing system** from Microport Systems, North Logan, UT, allows users to control workstations remotely and share high-speed graphics instantaneously over standard telephone lines. Users can converse on the same line using audio devices included with the system, while multimedia features provide visual and musical enhancements. The Drone™ component allows sales and training personnel to give demonstrations to remote sites.

For More Information Write In No. 706

DSP Development Corp., Cambridge, MA, has introduced the DADiSP/Neural Net backpropagation **neural network program**, a menu-driven module to help engineers and scientists incorporate neural nets into decision-support systems. An add-on to the company's DADiSP, the module provides the capability to build and train neural networks for applications such as pattern and speech recognition, image processing, and cluster anaylsis.

For More Information Write In No. 711



Dynamic Development Co., El Toro, CA has released Anti-Wear 1™, a **lubricant additive** that uses chemical grafting technology to modify the surface metallurgy of engine and transmission parts when mixed with motor oils, greases, and transmissions fluids. Originally developed for aerospace and industrial applications, the technology creates a new surface on metal parts and uses the pressure and temperature exerted on them to confer anti-wear and anti-friction properties. Company tests show that wear can be reduced to one-tenth of normal.

For More Information Write In No. 702

Edge Technology Inc., Waltham, MA, offers the ET4261, a 14-bit, 1-MHz **analog processor for charge coupled devices**. Through optimization of its differential input signal conditioner, low pass filter, correlated double sample, difference amplifier, and low noise 14-bit A/D converter, the device offers 14-bit performance and a usable dynamic range of 16,384:1. It also features low noise (1 LSB p-p) and differential non-linearity of ±0.5 LSB.

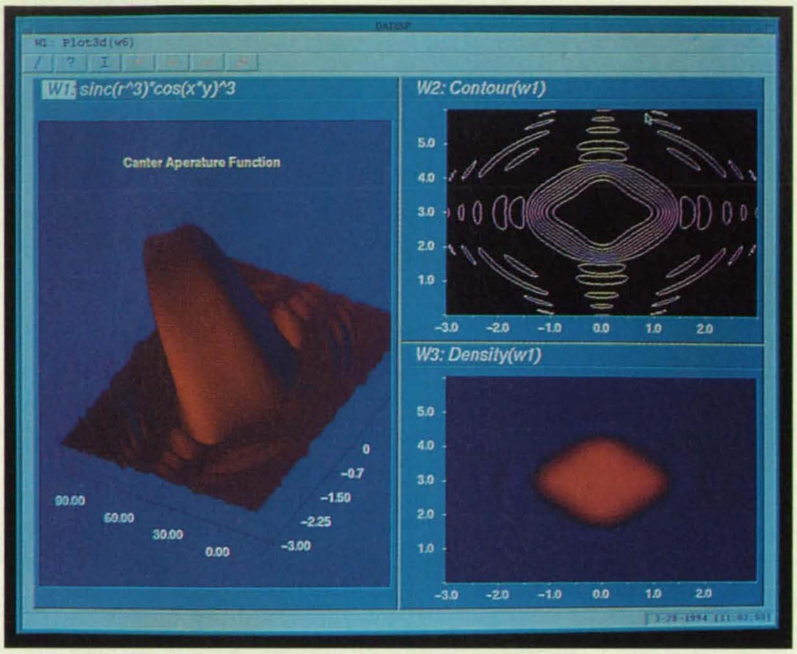
For More Information Write In No. 708

KVH Industries Inc., Middletown, RI, has introduced the Digital Gyro Compass (DGC™) and Digital Gyro Inclinometer (DGI™), **gyroscopic sensors** that can be embedded in other equipment requiring directional information. Priced at $795, the DGC can provide motor vehicle heading information, so a company can track units in its fleet or an emergency vehicle can pinpoint its location. The DGI, costing $995, provides roll, pitch, and azimuth rates, and may be applied in boat antennas, drones, and submersibles.

For More Information Write In No. 700

Super R™ Radiant Barrier from Innovative Insulation Inc., Arlington, TX, is a **reflective insulation** that turns back all low-wave radiation that strikes it and 97% of all radiant heat. Constructed of two thin layers of aluminum foil sandwiching a polyethylene reinforcing scrim, it can be used in industrial applications such as metal buildings, pipes, and concrete block construction.

For More Information Write In No. 703


DADiSP
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W1: sinc(r^3)*cos(x*y)^3
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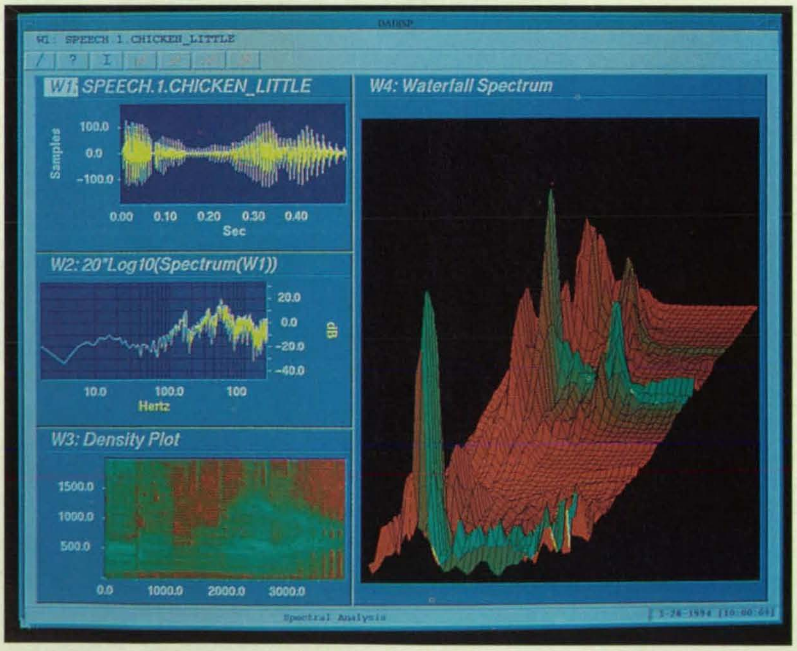
W2: Contour(w1)
W3: Density(w1)


W1: SPEECH.1.CHICKEN_LITTLE
W1: SPEECH.1.CHICKEN_LITTLE
W4: Waterfall Spectrum
Samples
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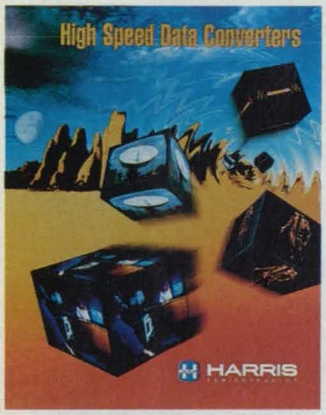
W2: 20*Log10(Spectrum(W1))
Hertz
W3: Density Plot
Spectral Analysis

New Literature

A quick and comprehensive reference to 21 **high-speed data converter ICs** has been released by Harris Semiconductor, Melbourne, FL. It provides performance parameters for 15 A/D converters with conversion speeds ranging from three to 500 million samples per second at resolutions from four to 12 bits. Six D/A converters with either eight- or ten-bit resolution feature update rates from 50 to 160 MHz.

For More Information Write In No. 719



Van Nostrand Reinhold, New York, NY, has published *The Complete Cyberspace Reference and Directory: An Addressing and Utilization Guide to the Internet, Electronic Mail Systems, and Bulletin Board Systems.* Opening with a glossary of terms, the book describes communication procedures for a variety of channels, including Internet FTP, Telnet, CompuServe, and MCI Mail. The directory offers more than 10,000 electronic addresses, while a disk includes a sampler of Chameleon from NetManage and an Internet front-end that provides e-mail and Telnet terminal emulation.

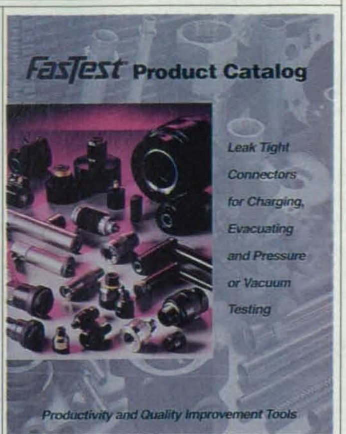
For More Information Write In No. 716

Power supplies ranging in output power from 15 watts to several kilowatts are spotlighted in a catalog from Farnell Advance Power Inc., Solon, OH. Products include single- and multi-output switch-mode, configurable switch-mode, and distributed power supplies. A product selector guide also is included.

For More Information Write In No. 720

A **test and measurement equipment** brochure from Bourns Inc., Riverside, CA, highlights 142 products such as encoders, panel controls, surge protectors, key and selector switches, and trimmers. Product categories include signal generators, communications equipment, multimeters, oscilloscopes, spectrum analyzers, and electrical recording and integrating instruments.

For More Information Write In No. 714

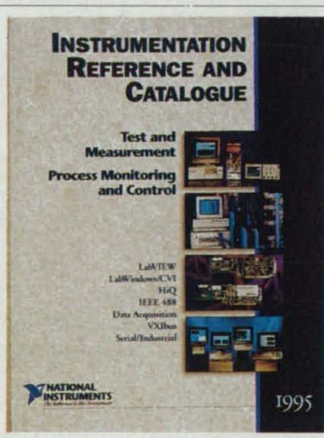


A guide to **leak-tight connections** published by Fastest Inc., St. Paul, MN, describes the company's air-actuated and manual connectors designed for industrial applications such as charging, evacuating, and pressure or vacuum testing. Automated, manual lever action and sleeve-action connectors can seal straight and formed tubes, threaded parts, and smooth or threaded ports.

For More Information Write In No. 718

A 480-page catalog of **metals and materials for research and industry** is available from Goodfellow Corp., Berwyn, PA. The more than 3600 items featured include pure metals, alloys, polymers, ceramics, composites, and honeycombs.

For More Information Write In No. 717



A 584-page products catalog from National Instruments, Austin, TX, describes more than 900 **software and hardware products used to develop integrated instrumentation systems** for test and measurement and process monitoring and control. New software products include HiQ® numerical analysis and data visualization software for Macintosh computers; LabVIEW® for HP-UX, Windows 3.1.J, and NEC Windows; and LabSuite, which combines LabVIEW and HiQ.

For More Information Write In No. 715

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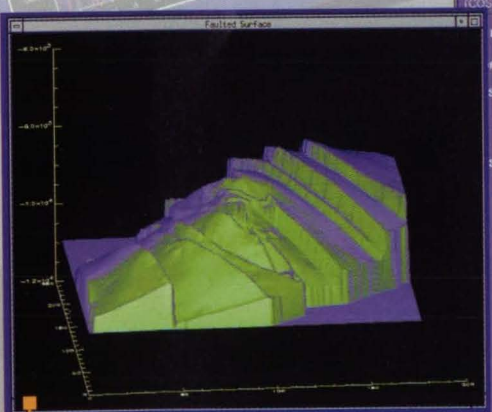

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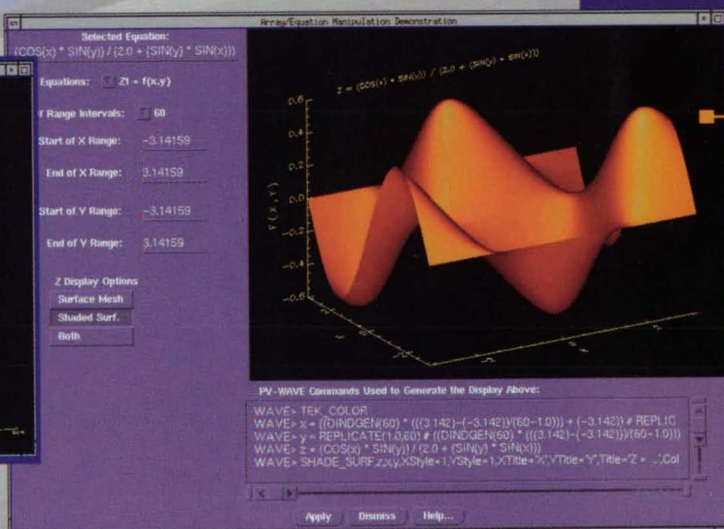

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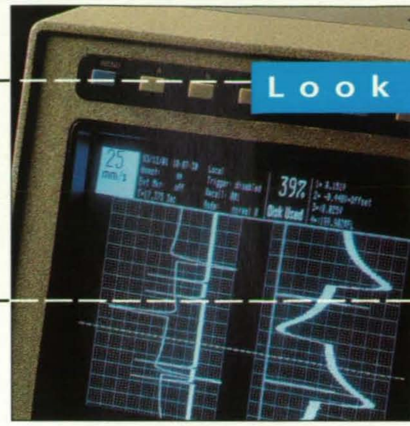
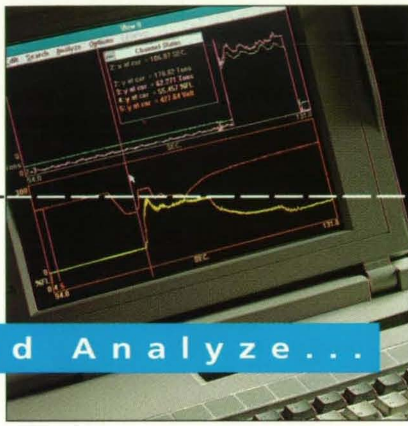
For More Information Write In No. 532

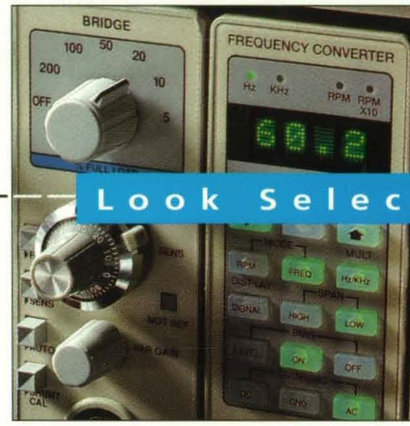
If you want to. . .



Look Now. . .

Look Later. . .

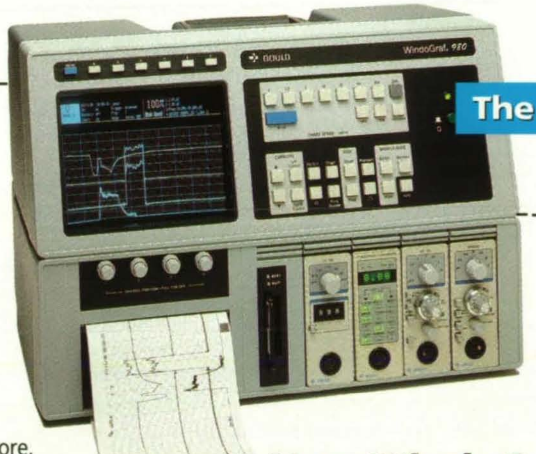




Look Selectively. . .

Look and Analyze. . .

Look no further.



The New WindoGraf 980

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WindoGraf 980 recorder. Look no further.

For More Information Write In No. 539

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NTB 1/9